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THE SOVIET SDI

Notable views of notable people on aerospace matters...

aerospace perspectives

By way of commemorating its 40th anniversary, *Commentary* magazine asked a group of distinguished intellectuals to address several specific questions under the general heading "How Has the United States Met Its Major Challenges Since 1945?" The request elicited thoughtful, often eloquent responses from 29 contributors, published in the November 1985 issue of *Commentary*. Excerpts from some of them follow.

William Barrett, *Distinguished Professor of Philosophy at Pace University:*

"There is no easy recipe for dealing with the nuclear question. Our disarmament would be equivalent to surrender, and it is questionable whether that would bring a genuine peace. At the present time, it seems to me, there is no other course to follow but to maintain all our strength and to remain prudent in its exercise. The presence of a potent but prudent power on the world scene might, who knows, serve to bring about a real international order in which genuine disarmament, with controls, might become possible."

Midge Decter, *executive director of the Committee for the Free World:*

"In the sense of the term, we do not have a policy and never have had. We have always pretended to ourselves that there is a third way—some complex tangle of deals and arrangements and settlements—between our seeing eventually to the Soviets' disappearance or their seeing to ours. Faced with a clear Soviet threat, in Central America, in the Middle East, in Southern Africa, we can be counted on to become a debating society, occupied with discussions about the root causes of social unrest in those troublesome places. We treat ourselves not as a party to the conflict, though it happens to be aimed directly at us, but rather as its mediator. We mediate, in other words, between ourselves and those out to destroy us.

"I do not say that this is a wholly unattractive trait. Bone and sinew of pluralistic democracy is the idea that varying interests can and must be mediated. This idea has done more than offer us a splendid country to live in; it has created a kind of political miracle in human history. The world, however, much as we would like it to be, and much as we once kidded ourselves into thinking it could be when we placed our hopes in an institution like the United Nations, is not a pluralistic democracy. The world is in fact a place where what little pluralistic democracy there is will be snuffed out if the citizens privileged to enjoy it are not prepared gratefully to begin making a few hard and clear choices."

Joseph Epstein, *author and editor of the American Scholar:*

"We have, then, this odd phenomenon, a country that seems to be increasingly conservative and a culture that remains for the most part solidly Left-liberal . . . Today, one feels that the culture is trailing the country. Marxist academic intellectuals, for example, rattling away about their dead doctrine, seem in a position akin to that of Galileo's returning to life to put forth the doctrine that the Earth is flat, when everyone else now knows better. If you were to put Elliot Cohen's third challenge—how successfully have we met the dangerous threat of totalitarianism?—to most members of the intellectual culture, I don't think they would know what the hell you were talking about. Totalitarianism for them is Caspar Weinberger, Henry Kissinger, Richard Nixon, Ronald Reagan. Which says a good deal, I think, about how successfully we are meeting the dangerous threat of totalitarianism."

Jeane J. Kirkpatrick, *former Ambassador to the United Nations:*

"Millions more have perished as victims of totalitarian governments than died in Hiroshima. The United States and the West have done far less well containing totalitarianism than in controlling the danger of nuclear war. There has been no nuclear war but more than a dozen countries have succumbed to ruling elites with totalitarian aspirations. The human consequences have been devastating. Millions have perished in purges, gulags and man-made famines without monuments, without marches, without international campaigns, without notice or sympathy. . .

"Why are there more anniversary vigils to the victims of Hiroshima than to victims of totalitarian governments? Why are more Western fears now focused on nuclear weapons than on the spread of totalitarianism? Why are so many of those most concerned about nuclear war among the least concerned about the spread of totalitarianism? What are the people who worry about nuclear war, but not about totalitarianism, actually worried about?"

Irving Kristol, *professor of social thought at New York University's Graduate School of Business Administration:*

"There have been three major and costly mistakes in American foreign policy (since 1945). They are: Yalta, Suez and Vietnam. Had it not been for the Yalta agreement, our troops could have moved to secure at least portions of what is now called 'Eastern Europe' . . . before their occupation by Soviet troops. Had it not been for our action at the time of Suez, some kind of international force could have been occupying the Suez isthmus since 1956, thereby averting the 1967 and 1973 Israeli-Arab wars, with their complicating consequences. And had it not been for the ineffectual mode of our intervention in Vietnam—'graduated response' it was solemnly called—we would not have experienced almost two decades of mass disorientation about the very legitimacy of any American foreign policy."

Walter Laqueur, *chairman of the research council of Georgetown University's Center for Strategic and International Studies:*

"I will be surprised if the coming years bring radical change in world affairs. My interest has been in history, and historians have on the whole been less shocked by foolishness, cruelty, lack of compassion, missed opportunities and various tragedies than sociologists and students of political science, simply because historians have been preoccupied with what actually happened rather than what should have happened."

Richard Pipes, *Baird Professor of History at Harvard University and former director of East European and Soviet Affairs at the National Security Council:*

"We have been quite unable to assimilate the view, which underpins the totalitarian outlook as well as practice, that conflict—in Russia's case 'class war'—is a permanent factor of history and though it need not take the form of a clash of arms, it will never cease until 'classes' are abolished, i.e., Communism triumphs globally. This adversarial relationship is repugnant to Americans, who regard conflict and violence as marks of failure. The whole effort of our foreign policy has been to ignore Communist ideology and concentrate on achieving a 'cooperative,' 'stable' relationship with Moscow, so as to create a favorable environment for global trade—which happened to be the very thing Moscow does not want. I doubt whether among the one hundred most influential persons in Washington under any administration there are as many as two or three who understand the source of our difficulty with the USSR, for whom the Soviet Union is neither a demon to be vanquished nor a victim to be accommodated, but a country run by people with their own values and objectives."

Eugene V. Rostow, *senior research scholar at Yale Law School, and former director of the Arms Control and Disarmament Agency:*

"The goal of Soviet diplomacy in arms control is to make it possible for the Soviet Union to achieve, enhance and consolidate a plausible first-strike capability based on a credible threat of retaliation. The Soviet leaders conduct their campaign of expansion with some prudence, so as not to arouse us too abruptly. But their psychology is that of men at war."

Edward Shils, *editor of* Minerva *and member of the Committee on Social Thought at the University of Chicago:*

"The ordinary mass of middle and working-class men and women of this country are suspicious of the Soviet Union, they dislike the society it enforces, and they suspect its intentions abroad. How and why do they maintain as much steadfastness in their patriotism as they do? For one thing, they are not educated or cultivated enough to believe in the fictions of the progressivistic intellectuals."

Albert Wohlstetter, *president of the European American Institute for Security Research:*

"Neither the United States nor the West European countries can really get a free ride. We are no longer able to defend our essential interests in the autonomy of Europe without Europe. And the Europeans surely cannot defend them without the United States, in part because their freedom, like ours, cannot be separated from the fate of some places outside the continent of Europe. Our genuine alternatives have to do with how to defend these interests in ways that complement each other. We are not doing very well. Nonetheless, it seems to me that both pessimism and optimism are only forms of self-indulgence. We have only the hard choices of finding out how to do better."

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On the cover: A Soviet Galosh antiballistic missile interceptor, part of an ABM system deployed around Moscow (see page 2).

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THE SOVIET

The Soviet Galosh antiballistic missile (ABM), capable of intercepting warheads in space.

"If you read only domestic critics and Soviet propaganda," said Defense Secretary Caspar W. Weinberger in a recent speech, "you would think that the Strategic Defense Initiative (SDI) emerged full-blown from our minds without reference to Soviet capabilities or strategic history."

Not so, the Secretary continued. SDI resulted from a thorough assessment of Soviet strategic capabilities, intentions and ongoing programs, including a research effort that almost exactly mirrors SDI. In other words, SDI was born of defensive necessity, not of American intent to gain strategic superiority.

The existence of a Soviet counterpart to SDI is an important point in the heated international debate on the subject. How can the USSR logically charge that SDI destabilizes the balance of deterrence and threatens a new escalation in the arms race when they—the Soviets—are conducting a matching program that is more extensive and of earlier origin? The Soviet Union, said Weinberger, is spending 10 times as much on strategic defense as is the U.S. and Soviet "hypocrisy on this issue reaches truly Orwellian proportions."

In his speech on "Strategic Defense and American Strategy," Weinberger recited the factors that brought the decision to start SDI, a research program to determine which concepts of defense against strategic weapons are feasible:

"When President Reagan took office . . . our broad examination of the strategic nuclear context led to a very troubling conclusion: the Soviet Union had rejected the notion of deterrence through agreed mutual vulnerability. In fact, the Soviets had been modernizing and increasing their offensive arsenal and simultaneously stepping up their

Soviet Strategic Defense Programs

(A Condensation)

Introduction

In the late 1960s, given the state of defensive technology at the time, the United States came to believe that deterrence could best be assured if each side were able to maintain the ability to threaten retaliation against any attack and thereby impose on an aggressor costs that were clearly beyond any potential gains. That concept called for a reduction by both the Soviet Union and the United States in their strategic defensive forces, the maintenance of a balance between the two sides' offensive nuclear forces, and negotiated nuclear arms reductions which would maintain the balance at progressively lower levels.

In accordance with those principles, the United States exercised great restraint in offensive nuclear arms and at the same time dramatically lowered its defensive forces.

The Soviet Union, however, failed to show the type of restraint, in both strategic offensive and defensive forces, that the United States hoped for when the SALT process began. The USSR has consistently refused to accept meaningful and verifiable negotiated reductions in offensive nuclear arsenals. Since the late 1960s, the Soviets have greatly expanded and modernized their offensive nuclear forces and invested an approximately equal sum in strategic defenses. The USSR has an extensive, multifaceted operational strategic defensive network which dwarfs that of the United States as well as an active research and development program in both traditional and advanced defenses against ballistic missiles.

Soviet offensive and defensive force developments pose a serious challenge to the West. If left unchecked and unanswered, they would undermine our ability to retaliate effectively in case of Soviet attack. The situation would be even more severe if the Soviet Union were to have a monopoly on advanced defenses against ballistic missiles in addition to its sizable offensive and defensive forces. In that case, the USSR might come to believe that it could launch a nuclear attack against the United States or our

SDI

By JAMES J. HAGGERTY

Illustrations courtesy Department of Defense

defensive programs—all with the clear aim of gaining a first-strike capability.

"No responsible leader could ignore this threat. Indeed, we joined the previous Administration—with whom we had some notable differences—in demanding modernization of our strategic arsenal to reverse the increasing vulnerability of our nuclear forces and the consequent erosion of our deterrent capabilities.

"Since strategy cannot be isolated from the threat, we had to consider the Soviet doctrine on nuclear war *and* their capabilities . . . Though many Western analysts believe that offensive technology will forever dominate defensive efforts, that is not the case in Soviet military doctrine . . . The Soviets did not let their massive buildup of superior offensive forces . . . preclude seeking the advantages of purely defensive systems. They did both."

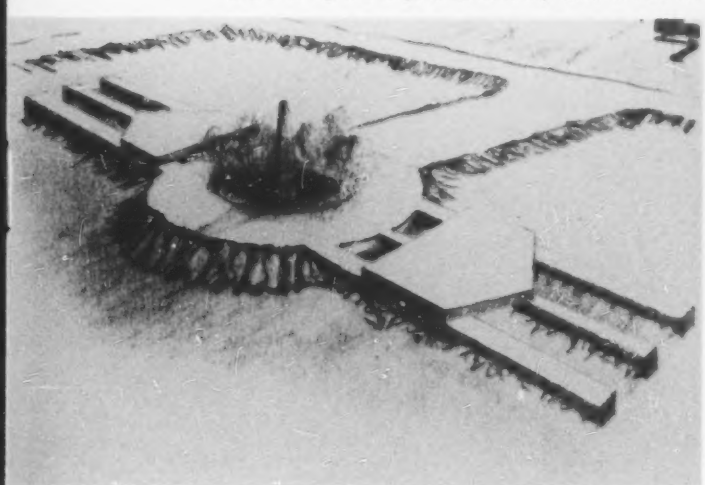
In the years since 1971-72, when the SALT I agreement and the antiballistic missile (ABM) treaty were signed, the Soviets have spent roughly as much on strategic defense systems as on their enormously expensive offensive strategic programs, Weinberger said. In the wake of those treaties, he added, the U.S. abandoned its single ABM site and, until SDI, virtually gave up on defensive systems. The Soviets, on the other hand, went ahead with development of what is today the world's only operational ABM system, one that is already being upgraded. In addition, they are constructing—in "clear violation" of the ABM treaty—a missile detection and radar tracking system. Weinberger continued:

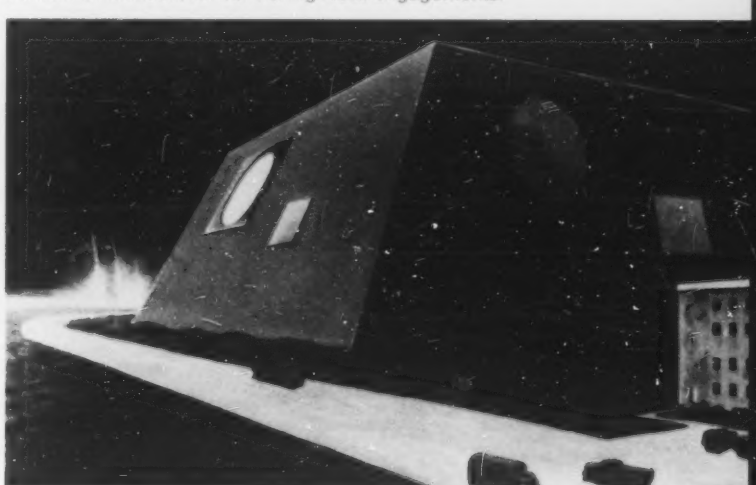
"The Soviet Union has also developed rapidly deployable ABM engagement radars and interceptor missiles. They have probably tested surface-to-air missiles, normally used against bombers, to intercept ballistic missiles . . . Additionally, Soviet research into advanced strategic defense technology—such as particle beam weapons, radio frequency weapons, kinetic energy weapons and high-energy lasers—has been extensive. More than 10,000 of their scientists and engineers are involved in this effort and, in some cases, they have made great progress well beyond the research stage—for example, the Soviets now have ground-based lasers that could interfere with our satellites. By the late 1990s, they could have prototypes of ground-based lasers able to hit ballistic missiles."

Western officials and commentators have uttered or written millions of words on SDI and strategic weaponry in general, but there has been little discussion of this immense Soviet strategic defense program—whether for fear of antagonizing the Soviets or from real ignorance of the scope and implications of the "Soviet SDI." Thus, a highly pertinent factor in the great international debate, one that might have strong influence on allied public opinion, has remained relatively obscure.

The U.S. is trying to do something about that, with speeches like Weinberger's and large-scale distribution of an impressive supporting document—*Soviet Strategic Defense Programs*—that details existing Soviet capabilities in air defense and ballistic missile defense and spotlights Soviet R&D in progress on advanced defenses. These pages contain a condensed version.

At left, a new Soviet silo-based high acceleration ABM interceptor, designed to engage targets within the atmosphere; at right, a large phased-array radar at Pushkino, northeast of Moscow, for controlling ABM engagements.





allies without fear of effective retaliation. At the very least, it might see a realistic chance of successful nuclear blackmail.

The Soviet Approach

The Soviet emphasis on strategic defense is firmly grounded in Soviet military doctrine and strategy, which call for the following actions in the event of nuclear war:

- destruction and disruption of the West's nuclear-associated command, control, and communications;
- destruction or neutralization of as many of the West's nuclear weapons as possible on the ground or at sea before they could be launched;
- interception and destruction of surviving weapons— aircraft and missiles—before they reach their targets; and
- protection of the Party, the State, military forces, industrial infrastructure, and the essential working population against those weapons that survived attacks by Soviet offensive forces.

Defensive Forces

Over the last 25 years the Soviets have increased their active and passive defenses in a clear and determined attempt to blunt the effect of U.S. and allied retaliation to any Soviet attack. Passive defenses are non-weapons measures—such as civil defense and hardening—which protect important assets against attack. Active defenses utilize weapon systems to protect national territory, military forces, or key assets.

The Soviet emphasis on the necessity of research into defenses against ballistic missiles was demonstrated by then-Minister of Defense Grechko shortly after the signing of the ABM Treaty in 1972, when he told the Soviet Presidium that the Treaty "places no limitations whatsoever on the conducting of research and experimental work directed towards solving the problem of defending the country from nuclear missile strikes."

Ballistic Missile Defense

The Soviets maintain the world's only operational ABM system around Moscow. In 1980, they began to upgrade and expand that system to the limit allowed by the 1972 ABM Treaty. The original single-layer Moscow ABM system included 64 reloadable above-ground launchers at four complexes and Dog House and Cat House battle management radars south of Moscow. Each complex consisted of Try Add tracking and guidance radars and Galosh interceptors nuclear-armed, ground-based missiles designed to intercept warheads in space shortly before they reenter the Earth's atmosphere. (Editor's note: The system designations are NATO code names.)

When completed, the modernized Moscow ABM system will be a two-layer defense composed of silo-based, long range, modified Galosh interceptors; silo-based, high acceleration interceptors designed to engage targets within the atmosphere; associated engagement and guidance radars; and a new large radar at Pushkino designed to control ABM engagements. The silo-based launchers may be reloadable. The new system will have the 100 ABM launchers permitted by the ABM Treaty and could be fully operational by 1987.

The Soviet system for detection and tracking of ballistic missile attack consists of a launch-detection satellite network, over-the-horizon radars, and a series of large phased-array radars.

The current launch-detection satellite network can provide about 30 minutes warning of any U.S. ICBM launch and determine the general origin of the missile. Two over-the-horizon radars directed at the U.S. ICBM fields also could give 30 minutes warning.

The next operational layer of ballistic missile detection consists of 11 large Hen House ballistic missile early warning radars at six locations on the periphery of the USSR. These radars can distinguish the size of an attack, confirm the warning from the satellite and over-the-horizon radar systems, and provide target-tracking data in support of anti-ballistic missile forces.

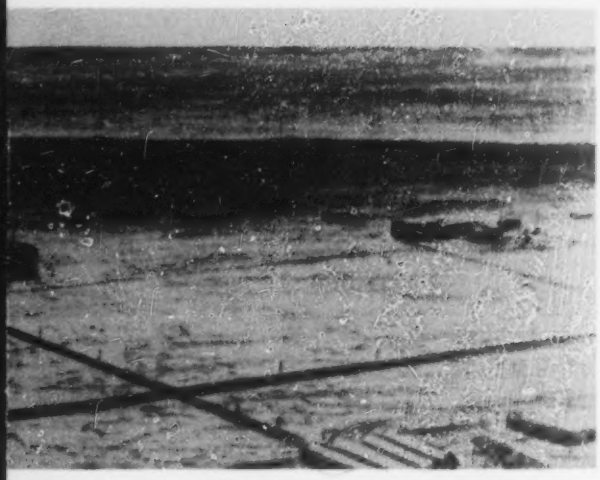
The Soviets are now constructing a network of six new large phased-array radars that can track more ballistic missiles with greater accuracy than the existing Hen House network. Five of these radars duplicate or supplement the coverage of the Hen House network, but with greatly enhanced capability. The sixth, under construction near Krasnoyarsk in Siberia, closes the final gap in the Soviet early warning radar coverage against ballistic missile attack.

The Kranoyarsk radar is designed for ballistic missile detection and tracking, including ballistic missile early warning, and violates the 1972 ABM Treaty. It is not located within a 150-kilometer radius of the national capital (Moscow) as required of ABM radars, nor is it located on the periphery of the Soviet Union and pointed outward as required for early warning radars.

The Soviet Union has claimed that the

The receiver and transmitter of the large phased-array ballistic missile detection and tracking system at Krasnoyarsk.

A network of Hen House ballistic missile early warning radars provides alert and target tracking data in support of the operational Soviet ABM system.



The directed-energy R&D site at Sary Shagan includes ground-based lasers that could be used in an antisatellite role today and possibly as a ballistic missile defense system in the future.

Krasnoyarsk radar is designed for space tracking, rather than ballistic missile early warning, and therefore does not violate the ABM Treaty. Its design, however, is not optimized for a space-tracking role and the radar would, in any event, contribute little to the existing Soviet space tracking network. Indeed, the design of the Krasnoyarsk radar is essentially identical to that of other radars that are known—and acknowledged by the Soviets—to be for ballistic missile detection and tracking, including ballistic missile early warning. Finally, it closes the last remaining gap in Soviet ballistic missile detection coverage. The Krasnoyarsk radar, therefore, is being constructed in direct violation of the ABM Treaty.

In addition, the Soviets have probably violated the prohibition on testing surface-to-air missile (SAM) components in an ABM mode by conducting tests involving the use of SAM air defense radars in ABM-related testing activities. Moreover, the SA-10 and SA-X-12 SAM systems may have the potential to intercept some types of strategic ballistic missiles.

Taken together, all of the Soviet Union's ABM and ABM-related activities are more significant—and more ominous—than any one considered individually. Cumulatively, they suggest that the USSR may be preparing an ABM defense of its national territory.

Advanced Technologies

In the late 1960's in line with longstanding emphasis on strategic defense, the Soviet Union initiated a substantial research program into advanced technologies for defense against ballistic missiles. That program covers many of the same technologies involved in the U.S. Strategic Defense Initiative, but represents a far greater investment of plant space, capital, and manpower.

Laser Weapons

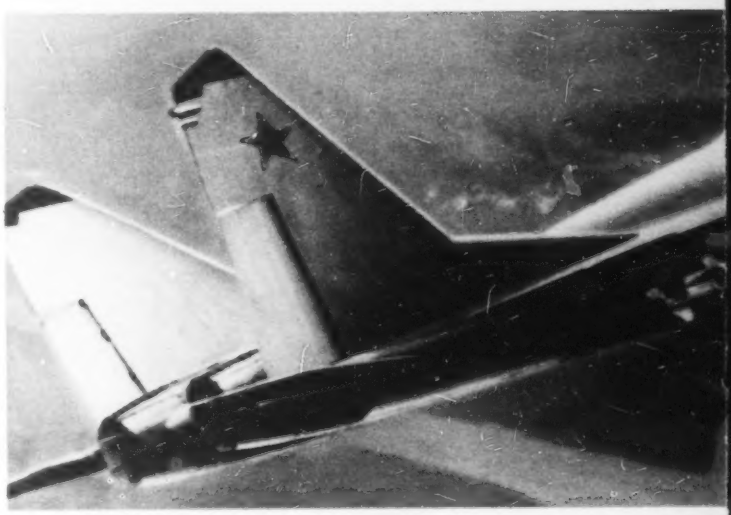
The USSR's laser program is much larger than U.S. efforts and involves over 10,000 scientists and engineers and more than a half dozen major research and development facilities and test ranges. Much of this research takes place at the Sary Shagan Missile Text Center where the Soviets also conduct traditional ABM research. Facilities there are estimated to include several air defense lasers, a laser that may be capable of damaging some components of satellites in orbit, and a laser that could be used in feasibility testing for ballistic missile defense applications. A laser weapon program of the magnitude of the Soviet effort would

cost roughly $1 billion per year in the U.S.

Unlike the U.S., the USSR has now progressed in some cases beyond technology research. It already had ground-based lasers that could be used to interfere with U.S. satellites and could have prototype space-based antisatellite laser weapons by the end of the decade. The Soviets could have prototypes for ground-based lasers for defense against ballistic missiles by the late 1980s, and could begin testing components for a large-scale deployment system in the early 1990s.

The remaining difficulties in fielding an operational system will require still more development time. An operational ground-based laser for defense against ballistic missiles probably could not be deployed until the late 1990s or after the year 2000. If technology developments prove successful, the Soviets may deploy operational space-based antisatellite lasers in the 1990s, and might be able to deploy space-based laser systems for defense against ballistic missiles after the year 2000.

In operational service is a Soviet orbital antisatellite (ASAT) weapon designed to destroy space targets with a multipellet blast.



The MiG-29 Fulcrum is one of three new highly advanced interceptors in the Soviet air defense system.

Particle Beam Weapons

Since the late 1960s, the Soviets have been involved in research to explore the feasibility of space-based weapons that would use particle beams. We estimate that they may be able to test a prototype particle beam weapon intended to disrupt the electronics of satellites in the 1990s. A weapon designed to destroy satellites could follow later. A weapon capable of physically destroying missile boosters or warheads probably would require several additional years of research and development.

It is still uncertain whether ground-based charged particle-beam weapons are feasible—that is, whether the beam will propagate in the atmosphere. A space-based neutral particle beam weapon, however would not be affected by the atmosphere or by the Earth's magnetic field.

Soviet efforts in particle beams, and particularly on ion sources and radio frequency quadrupole accelerators for particle beams, are very impressive. In fact, much of the U.S. understanding as to how particle beams could be made into practical defensive weapons is based on Soviet work conducted in the late 1960s and early 1970s.

Radio Frequency Weapons

The USSR has conducted research in the use of strong radio frequency signals that have the potential to interfere with or destroy critical electronic components of ballistic missile warheads. The Soviets could test a ground-based radio frequency weapon capable of damaging satellites in the 1990s.

Kinetic Energy Weapons

The Soviets also have a variety of research programs underway in the area of kinetic energy weapons, using the high-speed collision of a small mass with the target as the kill mechanism. In the 1960s, the USSR developed an experimental "gun" that could shoot streams of particles of a heavy metal such as tungsten or molydenum at speeds of nearly 25 kilometers per second in air and over 60 kilometers per second in a vacuum.

Long-range, space-based kinetic-energy systems for defense against ballistic missiles probably could not be developed until the mid-1990s or even later. The USSR could, however, deploy in the near-term a short-range, space-based system useful for satellite or space station defense or for close-in attack by a maneuvering satellite. Soviet capabilities in guidance and control systems probably are adequate for effective kinetic energy weapons for use against some objects in space.

Antisatellite Developments

The USSR has had for more than a dozen years the world's only operational antisatellite system, a co-orbital device which enters into the same orbit as its target satellite and, when it gets close enough, destroys the satellite by exploding a conventional warhead. In addition, the nuclear-armed Galosh ABM interceptor deployed around Moscow may have ASAT capability, and Soviet ground-based lasers could possibly damage some sensors on some U.S. satellites.

Furthermore, as noted earlier, the Soviets are engaged in research and, in some cases development, of weapons

which ultimately may serve as ballistic missile defense systems, but probably will first provide antisatellite capabilities.

Air Defense

Although the United States began dismantling most of its defenses against Soviet bombers in the 1960s, the Soviet Union has continued to invest enormous resources in a wide array of strategic air defense weapon systems. Taken together, the Soviet strategic air defense network is a potent and increasingly capable force which would attempt to limit the retaliatory capability of our strategic bombers and cruise missiles.

The Soviets have deployed numerous strategic air defense systems with excellent capabilities against aircraft flying at medium and high altitudes. They are now in the midst of a major program to improve their capabilities against aircraft and cruise missiles that fly at low altitudes.

Currently, the Soviets have nearly 12,000 SAM launchers at over 1,200 sites, 10,000 air defense radars, and more than 1,200 interceptor aircraft dedicated to strategic defense. An additional 2,800 interceptors assigned to Soviet Air Forces (SAF) could also be employed in strategic defense missions. In contrast, the U.S. has approximately 300 interceptor aircraft based in the U.S. dedicated to strategic defense, 118 strategic air defense warning radars, and no operational strategic surface-to-air missile launchers.

In flight test status is the SA-X-12 surface-to-air missile, designed to counter high performance aircraft but also capable of defending against tactical ballistic missiles and possibly some strategic missiles.

Soviet strategic surface-to-air missiles provide low-to-high altitude barrier, area and terminal defenses under all weather conditions. Five systems are now operational: the SA-1, SA-2, and SA-3, and the more capable SA-5 and SA-10.

In keeping with their drive toward mobility as a means of weapons survival, the Soviets are developing a mobile version of the SA-10 which could become operational late this year. This mobile version could be used to support Soviet theater forces and to permit periodic changes in the location of SA-10 sites within the USSR so as to counter U.S. retaliatory forces more effectively.

The Soviets are also flight-testing another important mobile SAM system, the SA-X-12, which is able to intercept aircraft at all altitudes, cruise missiles and short-range ballistic missiles. The SA-10 and SA-X-12 may have the potential to intercept some types of strategic ballistic missiles as well. This is a serious development because these systems are expected to be deployed widely through-out the Soviet Union in the 1980s. They could, if properly supported, add a significant point-target defense coverage to a nationwide Soviet ABM deployment.

Soviet Statements on SDI

These extensive Soviet activities in strategic defense, combined with the large Soviet buildup in offensive forces over the past two decades, have been eroding the retaliatory capabilities of U.S. strategic forces on which deterrence has long rested. If the USSR in the future were unilaterally to add an effective advanced defense against ballistic missiles to its offensive and other defensive forces, it would pose a very serious threat to U.S. and allied security.

The U.S. Strategic Defense Initiative is designed to counter the trend in the Soviet s favor. It is thus not unexpected that Soviet reactions to the U.S. Strategic Defense Initiative have been strongly negative. Through an intensive, worldwide propaganda campaign, the USSR evidently hopes that it can dissuade the United States from pursuing this research program, thereby preserving the possibility of a Soviet monopoly that could give the USSR the uncontested damage-limiting first-strike capability that it has long sought. Thus, Soviet statements on the SDI must be seen in light of the extensive, long-term growth in Soviet offensive and defensive forces and of their major research effort to develop advanced weapons for defense against ballistic missiles.

Senators Barry Goldwater (left) and Sam Nunn head a bipartisan task force investigating defense problems.

Defense Organization

CONGRESS

Earlier this year, Senators Barry Goldwater and Sam Nunn, chairman and ranking minority member respectively of the Senate Armed Services Committee, formed the Task Force on Defense Reorganization. They are co-chairmen of the nine-Senator bipartisan group, which is reviewing problems relative to defense organization and procedures with stated intent to seek changes where needed in the next session of Congress.

In October, the Senate Armed Services Committee released a preliminary staff report entitled *Defense Reorganization: The Need for Change;* based on a two-year study, it presents a lengthy list of alleged defense deficiencies that require corrective action. Senators Goldwater and Nunn prefaced release of the report with a series of dual presentations on the Senate floor outlining what they see as the major problem areas.

One is Congress itself. In the first of their presentations, the task force leaders told their Capitol Hill colleagues, in blunt and candid language, that Congress is compounding the problems of defense and changes in Congressional oversight of defense matters are long overdue. Their reasons are detailed in the excerpted version that follows.

CONGRESSIONAL OVERSIGHT OF NATIONAL DEFENSE
(Excerpted from the Congressional Record)

Senator Goldwater: "I believe one of the most pressing problems we face today is the overwhelming nature of the annual budget process, which includes the budget resolutions, the authorizing and appropriations legislation. The budget process dominates the agenda of the Congress and is seriously degrading the quality of Congressional oversight of the Defense Department . . .

"We now spend days debating how much real growth we will give DoD instead of what it takes to defend U.S. interests against threats to those interests. The level of spending is decided without going through a careful analysis of our defense objectives and defense requirements. The key national security issues are barely touched in a superficial discussion of defense spending. The budget process distorts the nature of Congressional oversight by focusing primarily on the question of how much before we answer the key questions of what for, why and how well . . .

"Compounding the year-long review of the budget cycle is the increasing duplication of activity among committees. All three steps in the legislative cycle—budgeting, authorizing and appropriating—are assigned to separate committees. The three functions are supposed to be complementary, but in fact they are in large part redundant. The Constitution clearly intended that there be some duplication by creating two different chambers of Congress. But this duplication is out of control. Congress has to approve a defense budget three times each year and each time we make changes from the earlier direction.

"For DoD, the situation has become a nightmare. DoD witnesses now have to testify as many as six different times before six different committees of primary jurisdiction over DoD policy. More and more legislation affecting the Defense Department is reported from subcommittees with only the smallest interest in national security . . .

"We are at a critical time when change is absolutely essential. Congressional oversight of the Defense Department has degenerated into debate over the wrong issues and that irrelevant debate occurs more than once each year. Discipline in Congress has broken down. The discussion is becoming less substantive and balanced. As we direct that changes be introduced into DoD to improve overall national security, we must make change ourselves. I am casting the first stone and I am throwing it at our glass house here in the Congress."

Senator Nunn: "Before 1959, most activities of the Department of Defense were authorized permanently, with the Appropriations Committee determining the level of funding required for the coming year.

"All that changed in 1959 when Congress directed that all spending for the procurement of aircraft, missiles, and ships be authorized each year prior to consideration of any appropriation. This began a steady process that has resulted in subjecting virtually the entire DoD budget to annual authorization as well as the annual appropriation . . .

"I think the process of annual authorization was a good one, but it has now gone out of control. Annual authorizations provide a strong lever to influence defense policy and provide broad oversight. Unfortunately, we have come to abuse that lever; as the old saying goes: 'We have found the enemy and it is us.'

"The burden of the annual authorization and appropriation process has produced two specific problems. It has led to the trivialization of Congress' responsibilities for oversight and has led to excessive micromanagement . . .

"Last year the Congress made adjustments to over 1,800 separate programs in the Defense Department. It required reports that were 400-500 pages long to explain why we did what we did. In effect, the Members of Congress and the staff

IS PART OF THE PROBLEM

are focusing on the gains of sand on the beach, while we should be looking over the broad ocean and beyond the horizon.

"I have been a member of the Armed Services Committee for 13 years. With the exception of the NATO debate last year, I cannot remember when we have had a floor debate on our national military strategy and how well we are doing in carrying out that strategy. We have not had a serious debate about the important relationship between our national objectives, our military strategy, our capabilities and the resources to support that strategy. We all know that there are serious gaps in these important links . . .

"But we have not looked at alternatives which may be more appropriate for the day and the circumstances and the threat we face.

"These are precisely the questions that Congress is supposed to consider: Do we have a strategy that achieves our national goals and objectives? Do we have the resources to meet these commitments and support the strategy? What alternative approaches might we adopt for overcoming the strategy-forces mismatch? Those are the questions that Congress should focus on. .

"Instead we are preoccupied with trivia. Last year, Congress changed the number of smoke grenade launchers and muzzle boresights the Army requested. We directed the Navy to pare back its requests for parachute flares, practice bombs and passenger vehicles. Congress specified that the Air Force should cut its request for garbage trucks, street cleaners, and scoop loaders. This is a bit ridiculous. The current Congressional review of the defense program would make a fitting version of the popular game 'Trivial Pursuit.' More and more, that is what we are engaged in. Our preoccupation with trivia is preventing us from carrying out our basic responsibilities for broad oversight.

Congressional Micromanagement

"The second effect of annual authorizations and appropriations is to invite micromanagement. The scope of this problem is unbelievable . . .

"In 1970, Congress directed the Defense Department to conduct 36 studies. Last year Congress mandated 458 studies and reports of DoD. This is nearly a twelvefold increase in a period of 15 years . . .

"The micromanagement problem is getting worse at an alarming pace. These are just a few of the examples of provisions contained in this year's authorization bill, and there are many:

"It is now the sense of the Congress that the musical units of the armed forces must use U.S. manufactured organs and pianos when they provide entertainment for patriotic events. Our staff has nicknamed this the 'Wurlitzer amendment.'

"Congress directed the Secretary of Defense to study the feasibility of selling beef, pork, and lamb products from the United States in overseas commissaries. We didn't direct him to evaluate how well DoD could meet our overseas military commitments, however.

"Congress directed studies or reports on retirement benefits for Philippine Scouts.

"I could go on and on with these. Each of these studies could be justified on its own merits. But when you add up all of them and look at the total of what we are directing the Defense Department to do, the sum total is absolutely absurd. The micromanagement problem is out of control.

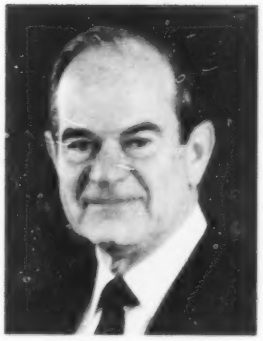
"If we are going to demand reform in DoD, we are going to have to reform ourselves. Congress needs to exercise some self-restraint. We need to restore discipline to the legislative process."

KEY PROBLEM—MICROMANAGEMENT

	1970	1976	1982	1985	Percent increase 1970-85
Requested studies and reports	36	114	221	458	1,172
Other mandated actions for DoD	18	208	210	202	2,022
General provisions in law	64	96	158	213	233
Number of programs adjusted					
In authorization	180	222	339	1,315	631
In appropriation	650	1,032	1,119	1,848	184

Senator Nunn presented these figures to show how Congressional micromanagement of defense has escalated since 1970: a twelvefold increase in Congressionally-mandated Department of Defense studies and a twentyfold increase in other Congressional assignments to DoD.

Improving Defense Procurement



By THOMAS G. POWNALL
Chairman and Chief Executive Officer
Martin Marietta Corporation

The defense industry today is close to being bankrupt in two important areas. It has a near zero balance in trust and confidence.

The press, many in Congress, a significant body of the Pentagon—including many of those in uniform inside and outside the Pentagon—the judicial system to a degree, and increasing numbers of the body-public appear to have determined that the defense industry is criminally guilty of fraud, waste, and abuse.

This is a severe challenge because it carries with it an unspoken suggestion of lack of patriotism. This I particularly resent.

The industry, nonetheless, does have a dwindling constituency. And in this democracy a free-enterprise defense industry cannot survive without public trust and confidence. In this regard, the industry's condition, in my view, is perilous. Weakened as it is, however, it has not yet suffered technologically, and its financial strength has not yet been impaired. But it will begin to suffer technologically and financially in the near-term unless trust and confidence are soon restored.

In offering these observations, and the recommendations that follow, I am not suggesting any special claim to perfection for myself or my company. In spite of our honest and diligent best efforts, we suffer the same human frailties as any other individual or large organization of people. I speak out only as a concerned member of an essential team in the interest of reason, balance and perspective.

The problems that have surfaced in the defense industry over the past two years are not unique to a single industry. Indeed, I have every confidence that if all industry and all government were examined in such intimate detail, the result would declare the defense industry to be the best—ethically and morally, as well as in terms of accomplishment. Never in history has so much money been spent by so many people with so little dishonesty.

In the process of restoring trust and confidence to the system, it is imperative that we differentiate—and that the public understands the difference—between human failings that result in what are basically administrative errors and those things committed with specific and willful intent to defraud. Everyone in the system—both in industry and government—deplores the latter and wants such behavior ferreted out and prosecuted to the fullest extent of the law. But care should be taken not to overreact, nor to brand with the same hot iron those smaller administrative errors resulting from misinterpretations or honest mistakes. They are equally regrettable and embarrassing, to be sure.

In a system that is largely people intensive, involving vast teams of individuals geographically separated but often working together on the same project, human frailty will surface occasionally. And as regrettable as that may be, restitution and systematic correction should be the response, including appropriate punishment of individuals where justified, but not wholesale retribution.

The large difference between yesterday and today is the motivation to make public even the smallest issue. This motivation is largely driven, I believe, by the growing conflict of defense requirements and the national deficit. As one Congressional staff member has put it, the defense industry in some respects has become a lightning rod for opponents of the administration's overall plans and policies. In this environment, is it any wonder that a spare part becomes a national scandal?

This country has a first class defense industry. It is dedicated foremost to the production and delivery of outstanding

products. It does this well, and this is not a hypothesis; it is an established fact. Its credibility is in the effectiveness of the systems it sends to the field.

Special rules and regulations have had to be evolved for the fair and efficient conduct of defense business. And a body of procurement regulations has arisen having the force and effect of law. These regulations have been exercised and fine-tuned for more than 40 years through a succession of court decisions, GAO rulings, Boards of Contract Appeal decisions, trade practices, prior course of dealings, and so on.

These market rules have served us well. We have a strong country and we have a strong defense industry base,

- a base which adds strength to our military posture through its frequently demonstrated capacity to advance the state of modern technology to a degree unsurpassed in any other society.
- a base which has demonstrated the capacity to expand to meet the nation's needs.
- a base which has produced weapon systems of such undeniable quality that they are sought the world over by both allies and adversaries.

These procurement rules also reflect a consensus as to what is fair, reasonable, and essential to the efficient conduct of business. But they also have grown complex over the passage of time. By virtue of their sheer number, the potential for mistake—honest mistake—has increased. Let me cite just one statistic: There were 15 million DoD procurement transactions in 1983. Even if the so-called horror stories totaled one-tenth of one percent, or 15,000—which they do not even come close to—that would leave 99.9 percent of the transactions acceptable. It would be difficult to claim a much better percentage for any business.

What is the fundamental problem with the acquisition process then? It does not suffer from lack of rules or regulations—never have there been more. It does not suffer from lack of laws governing procurement. In the last session of Congress alone, more than 160 measures directly affecting acquisition were introduced. It does not suffer from lack of internal attention—never has the procurement workforce been larger. Today, there are more auditors and investigators than ever before in our country's history. And it certainly does not suffer from a lack of media coverage.

What it suffers from is too much of all of the above. It has grown to the point of being so complex, so regulated, so overseen, so detailed, and so documented that it is difficult to do it right even when one tries his very best.

We should not blur the meaningful distinctions between fraud and misinterpretation. We should not confuse error with willful and wrongful misconduct. We should not resolve in criminal courts that which can be resolved at the negotiation table in a timely and efficient manner. We should not discard due process and fair play under the premise that the end justifies the means.

This is not a blanket defense for the prior actions of industry. There is need for continuing reform in the way we do business with the government. That reform, in fact, is a perpetual process.

Measurable progress has been made and will continue to be made if we are spared the tumult of constant and pervasive change in the rules at a rate which precludes timely promulgation, let alone understanding. In short, we are overmedicating the patient to the point that the treatment may prove worse than the disease.

By way of a thoughtful and constructive program for improvement, I would urge consideration of the following initiatives:

- Declare a moratorium on additional legislation pertaining to the conduct of the acquisition process until those regulations already legislated can be announced, understood, executed, and measured for effectiveness. While further new legislation would undoubtedly be well-intentioned, the greatest defense horror story of them all would be a rush of new laws that would decimate a system that has served our nation well throughout its history.
- Work diligently, with a sense of urgency, to clarify existing cost principles to minimize the many areas of ambiguity and confusion which give rise to the perception of wrongdoing on the part of contractors billing the government.
- Recognize the importance of profit as the means by which industry is better able to acquire the capital and resources to more efficiently and effectively pursue and perform government business and by which it stays on the cutting edge of galloping technology.
- Work hard to establish in the public's mind the credibility and genuine managerial skill of the Department of Defense in the conduct of acquisition to serve the urgent requirements of the nation's security.

By no means have all the government-initiated actions been excessive or misguided. So I would say to my colleagues in industry that we too should lend our weight and influence to bring about constructive change.

We must continue efforts to discourage waste or abuse and eliminate even the perception that it exists in the defense industry.

We must hold ourselves more accountable than ever, and expect others to hold us strictly to account.

We should, to the best of our ability, abide by the spirit of the regulations rather than hide behind ambiguities in the regulations.

We must reimpress our people with the conviction that nothing less than the highest standards of ethical practice are mandatory at all levels, and that we are very, very serious when we say that.

We must be constantly sensitive to the fact that it is the taxpayer's money that is being spent. Even more important, the nation's security is at stake. Our goal remains, as ever, to deliver the very best hardware in a timely manner and within the contract terms of cost and price—at the same time keeping in mind that profit is not a four-letter word.

I don't believe that it requires a highly qualified body of regulations to encourage a trusted executive—be he in industry or in government—to recognize and do what is right. The weight of monolithic, over-detailed regulations does more to crush the exercise of individual discretion than any other factor. What we can do, and ought to do, is devote less effort to composing and enforcing shotgun procedures and prohibitions and commensurately more effort to obtaining, training, and retaining personnel blessed with the qualities that would obviate such regulatory harassment.

I like doing business with the government. It has given my company and its employees the satisfaction of knowing that we are serving our country in a very meaningful way. We view our contracts with the government as joint undertakings to bolster the defense of our way of life.

We think what we are doing is important. And I think that the process of acquiring goods and services from private industry for the government's needs is by far the most cost-effective way to get the job done. If the present system is to survive, then we all must work hard, and honestly, and caringly, to improve the process every step of the way.

PROTECTIONISM: Costs Outweigh Benefits

For some time, America's declining trade posture has been a matter of serious concern among those responsible for U.S. economic policy and those U.S. industries whose livelihood is dependent in large measure on the sale of goods and services abroad. With the U.S. trade deficit deepening sharply each year, alarm has spread to the American public as a whole; it is reflected in some 300 protectionist bills, ranging from across-the-board import-surcharges to industry-specific measures, that have been proposed in Congress.

Renewed American productivity and competitiveness are the answers to the problem, not protectionism, says an Aerospace Industries Association paper. The reasons are stated in the accompanying abridgement of *Solving the U.S. Trade Problem—Protectionism or Competitiveness?*, copies of which are available from the Aerospace Research Center, Aerospace Industries Association, 1725 DeSales Street N.W., Washington, D.C. 20036.

The United States can and should solve its trade problems through sound monetary and fiscal policies and a strong commitment to competitiveness. Protectionism, on the other hand, will inhibit innovation and creativity. It will prevent American business and industry from making the necessary commitments of both financial and human resources. It will make us less flexible, less able to make the continual market adjustments that are necessary. Americans need to understand that while protectionism has its benefits, it also has its costs.

Further, protectionism in our international business relations is opposite to the approach we have taken domestically. In recent years, the United States has sought to increase the efficiency of the economy through deregulation and tax reform. This has sometimes involved a restructuring of industries, with dislocations for both firms and workers. The removal of Civil Aeronautics Board regulation of airline rates and routes, for example, put strong downward pressure on wages and other costs in the airline industry, but it allowed all airlines flexibility to respond to any combination of route and service level demanded by passengers. Some airlines were injured by these changes, but deregulation also encouraged new airlines and new types of services. Deregulation created change and uncertainty in aircraft manufacturing as well but the market, we decided, rather than the government, should make these economic choices.

However, the momentum is shifting away from economic efficiency in the U.S. trade policy when we move toward government intervention in the form of protection. Clearly, the worker forced out of a job or into a pay cut by imports is no worse off than one who lost his job because of some purely domestic factor. Is it economically justifiable to support and promote full and fair market principles domestically and not internationally?

The Benefits of Protection

In trading negotiations, a credible threat of protection is useful. Trading partners need to be aware that the United States has the ability and the willingness to block access to its market in response to unfair trade practices.

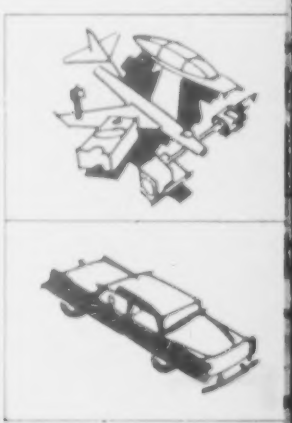
At present, U.S. trade policies provide specific responses to certain types of unfair trade practices, and in addition, Section 301 of the Trade Act provides a broad remedy for practices not specifically mentioned. This remedy was designed to be *discretionary*, allowing the President flexibility in integrating trade policy, foreign policy, and national security concerns. The President can thus weigh the importance of various issues in making a decision. The same policy that permitted the President to emphasize political and military control over economic concerns when the United States enjoyed a healthy balance of trade now allows him the flexibility to emphasize trade issues in the current environment of high trade deficits and, if necessary, to use the threat of protection as a means of securing access to closed markets. In short, current trade policies do provide leverage in U.S. negotiations for fair trade.

Protection does shelter U.S. industries from international competition, slowing down the dislocation of workers and firms in a specific industry, but these benefits are political rather than economic when viewed from a national perspective. The protection that slows down dislocation often has other influences which affect the market in ways that are not anticipated. The 'voluntary' export restraints on Japanese cars, for example, led the Japanese to produce more expensive and luxurious models, a market which has been highly profitable for U.S. automakers. A result of high sugar prices due to protection is that the U.S. soft drink industry, among others, has turned to corn sweeteners as a sugar substitute. Protection can only change the form and speed in which international market forces affect an industry; it cannot prevent changes from occurring.

Until now, domestic political power has not directly influenced U.S. trade policy. While some industry groups have succeeded in securing protectionist legislation, the United States has been a leader in opening the world trading system. U.S. economic policies would be poorly served by a policy-making structure which rewards industries with protection based on their domestic political clout.

The Costs of Protection

Fair trade among countries brings sig-



nificant net economic benefits through the principle of comparative advantage. In the case of consumer goods, the principle can be demonstrated in the way trade among the states makes the U.S. as a whole wealthier. If Maine were to prevent the entry of Florida oranges, some Maine residents would prosper by growing greenhouse oranges; the major effect, however, would be a drop in the availability of oranges in Maine. At the same time, Florida would be profoundly affected due to lower levels of orange production. A similar effect has occurred in the international marketplace where the protected U.S. market price of sugar is approximately three times the world price. Consumers are the clear losers, paying higher prices for a wide range of foods and beverages.

Protection negates the principle of comparative advantage for industries—even before the threat of retaliation is factored in. The low international price of copper has forced some U.S. domestic mines out of business, leading to dislocation of firms and workers in copper producing areas. However, protection leading to higher copper prices would have had other deleterious effects. Firms using copper in other articles such as pipes, wiring, electrical components, etc., would pay more for copper and their goods would be priced higher. Protection for copper producers would negate any comparative advantage that manufacturing firms using copper might have and could be a factor in the competitiveness of those firms, vying for business with firms who paid less for copper, in the international marketplace. Domestic companies would even be at a disadvantage in the U.S. market unless protection was extended to all imports containing copper. Rather than solving any of our economic problems, protectionism creates a whole host of new problems.

Protectionism also impedes the continual process of adjustment that takes place in an economy. The location of many high technology companies around Boston was due in part to the depressed nature of the region after the departure of the textile and other traditional industries. High technology companies were drawn to the area because of the large labor pool. The existence of skilled and unskilled labor is a requirement for industrial growth, so the loss of jobs in one industry or region is part of a cycle that occurs continuously on both a local and a national scale. Rapidly growing sectors are hampered by protection if it prevents or discourages retraining and movement of workers into those growth industries.

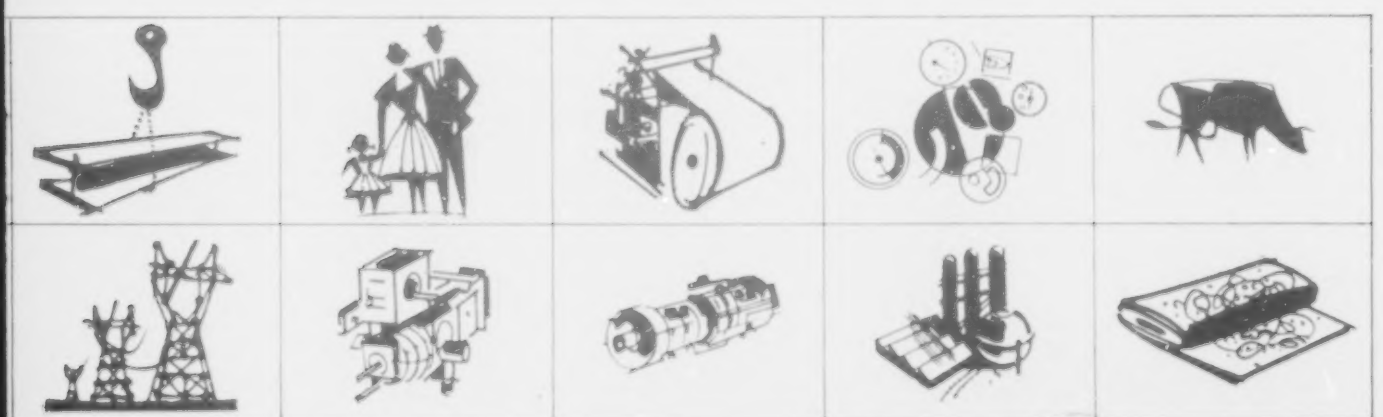
Since the costs of protection greatly exceed the benefits, what are the alternatives? Alternatives might include retraining and/or relocation programs which would entail lower costs to the nation and could increase the flexibility of the labor force. These programs can be costly, and they have their limitations, but they do provide a bargain in comparison with protection.

Retaliatory Response

Retaliatory measures can be expected as a response to U.S. protection. We have only to look at the disastrous consequences of the Smoot-Hawley tariffs, which were imposed after the stock market crash of 1929. Responding to high unemployment and political unrest, and in an effort to export U.S. joblessness, Congress enacted the high Smoot-Hawley tariffs in 1930. This protectionist legislation set off a series of retaliatory measures by other nations; prevented foreign nations from making payments on outstanding loans, since exports to the United States were their primary means of earning foreign exchange; and caused a contraction of world trade that seriously affected the income and employment levels of all nations. National economies have become increasingly interdependent since that time, and the effects of U.S. protectionist measures today would be even more immediate. The United States plays an important role in the international marketplace as both a buyer and seller of goods. If the United States restricts imports significantly, repercussions would be felt in most countries around the world. At best, the market for U.S. exports would be diminished, but it is also possible that the stability of the international economy would be jeopardized.

The United States was a leader in the trade liberalization period in the 1950s and 1960s, when giant leaps in income and standards of living were among the benefits of increased world trade. The ability of the United States to set the tone of world trade in the 1980s and 1990s should cause us to look beyond the short term political consequences of our actions. The image of the United States as a leader of the free world will be enhanced by enactment of policies that effectively deal with the real causes of the trade deficit, rather than politically expedient policies that deal only with symptoms.

The support being generated for protectionist legislation is raising expectations that new laws will provide answers to U.S. economic problems. Americans are expecting more jobs, increased competitiveness, a leveling of the value of the dollar and a lower trade deficit. These expectations will inevitably lead to frustration. Some of the protectionist legislation is at least as tough on Americans as it is on recalcitrant trading partners. Protectionism should be used only as leverage to obtain free markets around the world since protection involves sacrifices—not benefits—to the country that employs it. And protectionism is clearly inconsistent with our long-term national goal of being competitive in the world market for decades to come.



NASA BEYOND 2000

A significant expansion of the human population in space . . . a manned lunar base . . . mining activities on the moon and asteroids . . . high-payload sample return missions to distant planets and their moons . . . a superefficient 300-400 passenger second generation supersonic transport . . . and "transatmospheric" aerospace planes capable of flight within or outside the atmosphere. These are a few of the possibilities NASA sees in a "vision" of space and aeronautical progress beyond the year 2000.

The vision is contained in NASA's *1986 Long Range Program Plan*, an annual publication intended primarily for internal use, to let one NASA program office know what another has in mind. "Long range" usually means prospective program initiations for the next five fiscal years, with follow-on possibilities. This year NASA broadened its horizons and added—in addition to the customary near-term objectives—its visionary leap into tomorrow with the comment "it is none too soon to begin preliminary planning of possible systems, programs and activities for the early years of the 21st century." It is perhaps the most solid projection yet published, since it was prepared by people intimately engaged in ongoing research programs, knowledgeable about current and anticipated capa-

This artist's conception shows a 21st century lunar operation in which crews are mining ilmenite, a fairly common moonsoil component from which liquid oxygen can be produced. The ilmenite would be processed at a permanently manned lunar base; it would be used to support the base itself and facilities in Earth orbit.

bilities and occupationally conservative about predictions. For all that, the vision has a distinct Sunday supplement flavor.

The following is an encapsulated summary of what NASA sees for the "early 21st century;" the term "early" is not specifically defined but there are indications that it means, in most cases, the period 2000-2025.

Lunar Base

There will be a manned base on the moon and routine use of the lunar surface for planetary science studies, solar monitoring, astronomical surveys and—the report qualifies it with a "possibly"—extraction of resources. NASA thinks that techniques can be developed for mining, extracting and fabricating products from moon soil and rock. The oxygen—and other products made from lunar "feedstocks"—will allow the lunar base to support itself to some degree. Additionally, lunar oxygen can be delivered to Earth orbit for use in the Space Station or intermittently-manned orbital platforms, obviating the need for bringing oxygen up from Earth. Says the report: "Extraterrestrial resources also will be investigated by means of missions, manned or unmanned, to near-Earth asteroids to obtain information on and assess the availability of resources—especially the volatile elements carbon, hydrogen and nitrogen—that are lacking on the moon."

The space transportation vehicle linking the lunar base with the Space Station will be an advanced, manned version of the Orbital Transfer Vehicle already in preliminary development status.

Earth Observations

Earth will continue to be the most intensely studied planet. NASA will use a variety of sensors, aboard the Space Station and its associated platforms operating in polar and equatorial orbits, for continuous monitoring of Earth's land surfaces, atmosphere, oceans and the near-Earth environment. Development of advanced space transportation capabilities will allow continuous monitoring of larger areas of Earth from geostationary orbit and, later, human-tended instruments on the lunar surface will permit complementary observations of Earth's entire face with simultaneous investigation of Earth's space environment.

NASA touches only lightly on the underlying reason for such intense Earth scrutiny: "effectively monitoring Earth's environment will help humankind manage that environment wisely for the benefit of all." The idea is frequently advanced that a thorough understanding of the immensely complex forces that govern Earth could lead to the ability to manage such forces—control the weather, for example, or change the environment to avert potential disasters stemming from introduction of man-made pollutants to the atmosphere.

Solar System Exploration

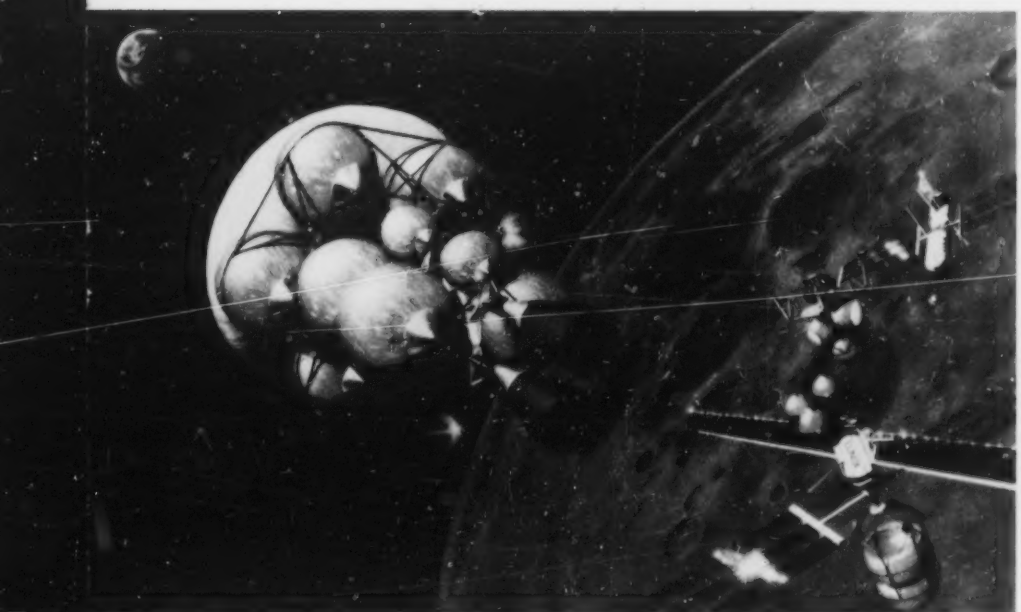
The Space Station and its platforms will serve as orbital bases for astronomical observations of Earth's sister planets; putting advanced telescopes into orbit, above the distorting layer of atmosphere, will make possible long-term observations of the planets at resolutions better than can be attained by Earth-based telescopes.

There will still exist a need for closeup studies of the planets and, where possible, return to Earth of planetary samples. This effort will build upon a comprehensive program that will begin in 1990 with the launch to Mars of the first of a series of planetary observer spacecraft for extensive investigation of individual planets. Also in the 1990s, NASA hopes to launch the first Comet Rendezvous and Asteroid Flyby mission; a comet sample return mission; a Lunar Geoscience Observer to assess lunar resources; and a Saturn Orbiter/Titan Probe mission for detailed examination of the ringed planet and its largest moon.

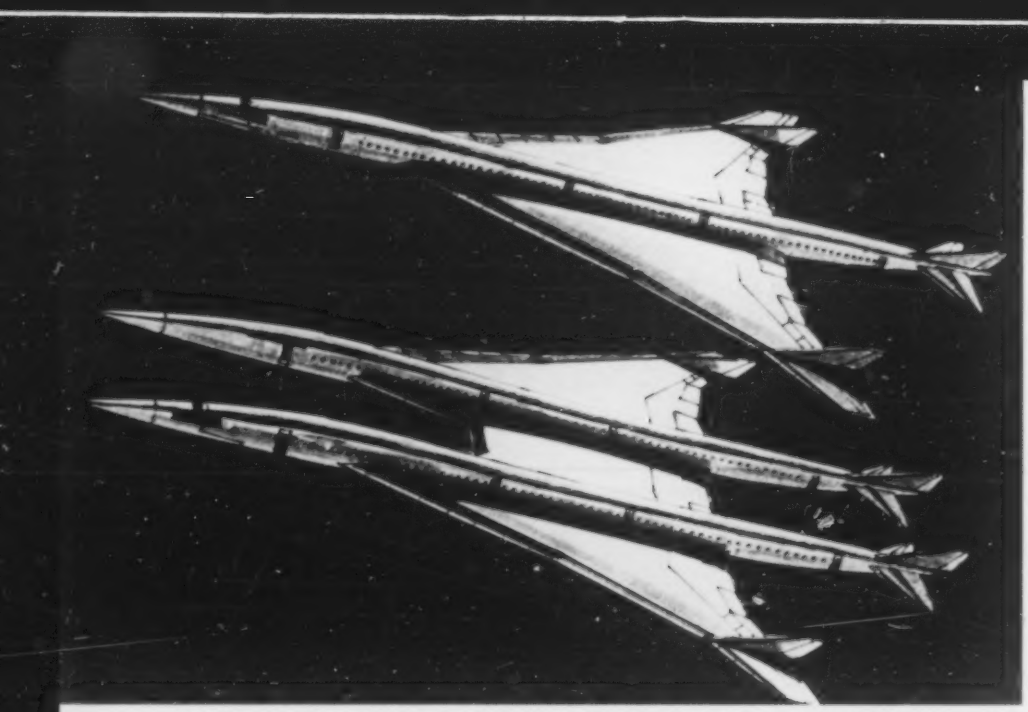
Around 2000, upper stage launch systems already being developed will enable certain advanced planetary missions, such as a sample return from Mars. Use of the Space Station as a launch base, coupled with development of more advanced, higher performance launch stages will make possible automated missions to planetary systems that are not now "easily accessible." Examples cited are a Mercury Orbiter mission, difficult now because of extraordinary propulsion requirements and the problems of making scientific investigations so close to the Sun; a Neptune Orbiter/Probe; long-term studies of the Jupiter and Saturn systems, including their many moons; and sample return missions of "greater sophistication." Among the latter is a rendezvous mission to Mars' moons Phobos and Deimos "to emplace instruments on and return samples from them." The report also contemplates detailed investigation of the Martian surface, to be carried out "either by large automated spacecraft or by a manned mission." That is the only mention of the much-proposed manned expedition to Mars.

Astrophysics and Solar Studies

The early 21st century will be a golden age for astronomy and astrophysics. NASA will study the universe beyond the solar system from Earth orbit, employing an assortment of spacecraft including small specialized missions and large observatory-class facilities. To be launch-



Ferry vehicles such as the one shown in left center would link the moon base with Earth orbital facilities, bringing up supplies and returning liquid oxygen and other products created from lunar resources.



NASA sees a second generation commercial supersonic transport in the early 21st century. The artist's concepts show low density (top) and high density versions of the same basic design.

ed next year, the Space Telescope will be the first of these king-size observatories and it will still be operating in the 21st century. It will be joined in the 1990s by other long-life, Space Station-serviced facilities such as the Gamma Ray Observatory, the Advanced X-ray Astrophysics Facility, the Advanced Solar Observatory and presumably, after 2000, by still more advanced observatories of increasing investigational capability. Together they will look back in time to the beginning of the universe, observing not only in visible light but in several bands of the spectrum, multiplying many times man's knowledge of the origin and evolution of the universe.

An exciting and scientifically important study planned for the 1990s and beyond is the detailed examination of a star—the closest one, the one we call the Sun. NASA has conducted many investigations of the Sun, but most of them have focused on the Sun/Earth relationship rather than the Sun as a representative star. Advanced capabilities in propulsion and spacecraft instrumentation may make possible the first look at the Sun's interior and provide enormously valuable information toward interpreting other stars. The studies will be carried out by the Advanced Solar Observatory, large Space Station-based sophisticated instruments for long-term monitoring, and such automated spacecraft as solar probes, orbiters and "grazers."

Life Sciences

Says the report: "The first quarter of the 21st century will see a major effort to develop protective systems and physiological countermeasures to qualify humans for space flight missions years in duration. A group of dedicated Space Station modules will provide space laboratory capabilities for this work. Among the most serious problems to be solved are bone demineralization, loss of muscle mass and radiation protection. Concurrently, operations and life sciences studies in a lunar surface can develop the information required to plan for human residence on other planets."

Aeronautics in the 21st Century

A number of technologies now in development will make turn-of-the-century subsonic airplanes safer, more productive and far more efficient. There will be continuing advances in subsonic aircraft well into the 21st century, particularly in automation of the tasks performed by aircrews, in general aviation as well as commercial service.

As population shifts and new urban areas develop, there will be increased need for advanced short-haul transports of 50 to 100 passengers or more, operating from small airports or from short runways at hub terminals; they may be powered by advanced turboprops now in development. In addition, NASA sees a generation of high speed (subsonic) rotorcraft—possibly of the tilt-rotor variety—serving as intercity transports, military airlifters or in such civil operations as rescue, emergency medical service and police work.

The most significant "challenges and opportunities," however, will be in supersonic and hypersonic flight. The long-discussed second generation supersonic transport may become a reality in the early part of the 21st century. The report states:

"The next century will be characterized by several trends that are almost certain to alter the outlook for long range transportation. World population will continue to grow and the largest component of that growth—over 75 percent—will be in the developing nations. The growth of population and industry in the Pacific Basin, South America, Asia and Africa—and the resulting increase in trade and multinational business—will create a market for over-ocean transportation with stage lengths considerably greater than those over the North Atlantic. Those long stages and the large fraction of travel that will be business-oriented, rather than tourist-oriented, will increase the value of reducing trip time and increasing productivity, and will precipitate renewed interest in supersonic transportation."

Studies indicate that an advanced technology supersonic transport could carry 300-400 passengers over intercontinental ranges at more than three times the speed and productivity of today's subsonic transports. The report adds: "Operating cost estimates suggest that little if any surcharges over tourist fares would be required and some congfiguration approaches appear to promise sonic boom overpressures that would be sufficiently low that flight over land would be practical."

Beyond the advanced SST, NASA provides a brief glimpse of the hypersonic era. Sustained hypersonic flight entails difficult problems in propulsion and aerodynamic heating; however, "research has indicated that they can be solved, making hypersonic operations in the next century practical and perhaps even routine."

The first operational hypersonic craft may be long range cruise missiles with supersonic combustion ramjet (scramjet) propulsion. The technologies developed for those missiles would provide a base for development of a strategic reconnaissance aircraft capable of very high altitude flight at Mach 5 to Mach 7 (roughly 3,500 to almost 5,000 miles per hour).

The ultimate vehicle suggested is the "hypersonic maneuvering airplane capable of sustained operations both in the atmosphere and in low orbit." Such a vehicle would be powered by a combination of scramjet and rocket propulsion systems to reach the 17,000 miles per hour speed required for orbit and it would probably be able to take off and land horizontally. This is the transatmospheric vehicle envisioned in the Aeronautical R&D Goals policy paper issued earlier this year by the White House Office of Science and Technology Policy. Its prime utility would be as a highly flexible, quick response space transportation system for civil or military orbital operations. But, although the Long Range Program Plan does not permit itself such a flight of fancy, the essential technology advancements would also offer an exciting civil transportation possibility: a "transatmospheric transport," one that could move passengers between any two points on Earth in less than two hours.

AEROSPACE: TECHNOLOGY PIONEER

In addition to large-scale employment, export sales and a major contribution to the Gross National Product, the aerospace industry plays another vital role in the U.S. economy: it advances new technologies, improving them and driving down costs to the benefit of other industries, thus enhancing the productivity of the nation as a whole. This technology advancement process is the subject of a study report—*Technology Diffusion, The Movement of Technology Between Aerospace and Other Industries*—published by Aerospace Industries Association's Aerospace Research Center.

In 1984, says the report, the U.S. aerospace industry led the nation in R&D investment and such commitment is important not only to aerospace but to the entire U.S. economy because "aerospace serves as a pioneer, opening up new industrial technologies which ultimately strengthen many other U.S. industries as well. Without a strong aerospace industry, the technological competitiveness of other U.S. industries would suffer."

The study focuses on three representative technologies in which the U.S. aerospace industry played a significant pioneering role. They are turbocharging technology for improving engine efficiency; fiber reinforced plastics, composite materials that are generally lighter yet stronger than metals; and computer-aided design/computer-aided manufacturing (CAD/CAM), processes for improving design, analysis and production efficiency through automation.

Turbochargers. The turbocharger was not an aviation invention; it was first applied, with little success, to diesel powerplants in ships, locomotives and factories. However, its initial use in a gasoline engine was in a 1917 research project sponsored by NACA, NASA's predecessor. Interest in turbocharged aircraft engines boomed in World War II, providing a strong technology base that led to gradually increasing automotive applications in the postwar years—initially in diesel trucks, then in off-highway equipment, eventually in automobiles. The turbocharger market in North America alone has grown from about 10,000 units in 1955 to an estimated 600,000 in 1985.

Fiber reinforced plastics. Experienced gained in aviation use of fiber reinforced plastics, or FRPs, during the 1940s led directly to a 1950s revolution in recreational boating, featuring FRP hulls for power boats, sailboats and canoes that allowed sharp reductions in construction and maintenance costs. FRPs have since spread to a wide range of other recreational uses, automotive applications, appliances and other non-aerospace products. There has been parallel growth in aviation applications; current jetliners contain 10-15 percent FRP materials and the figure is expected to rise to 65 percent within 10 years. Aerospace development of FRPs has improved their cost, strength, stability and reliability and spurred ever-widening non-aerospace applications. Estimates indicate that FRP use will grow at an annual rate of 30-50 percent for the next 15-20 years.

Computer-aided design and manufacturing. CAD/CAM systems were first applied by the aerospace industry in the 1950s to reduce the time spent in design, testing and defect correction. Aerospace experience led to creation of a whole new industry providing CAD/CAM systems tailored to the special needs of various industries. In the 1980s, CAD/CAM systems capable of being directed by low-cost personal computers extended the technology to the smallest businesses. By pioneering CAD/CAM, the aerospace industry made the technology economically attractive to other industries, thus improving national productivity and quality, hence international competitiveness.

These and many other examples of how the aerospace industry serves as a "technological engine" have not gone unnoticed by foreign nations; the potential for economic benefit through technology transfer is one reason why other countries are actively promoting, often subsidizing, their aerospace industries.

Since 1970, the U.S. share of the free world aerospace market has declined in every major market segment: airframes, engines, equipment and space. To the extent that U.S. aerospace continues to lose market share, the nation will be losing an important stimulus for development in other U.S. industries. Says the report:

"Aerospace is one of several key industries of today and tomorrow—other such industries are electronics, telecommunications, biotechnology, computers and advanced materials. Unless the importance of these pioneering industries is properly understood and valued in the United States, their erosion through loss of market share will have a severe long-term impact on the international strength and competitiveness of the entire U.S. economy."

Copies of *Technology Diffusion* are available from the Aerospace Research Center, Aerospace Industries Association, 1725 DeSales Street N.W., Washington, D.C. 20036.

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AEROSPACE REVIEW AND FORECAST 1985/86

A WINDOW OF OPPORTUNITY

By KARL G. HARR, JR.
President
Aerospace Industries Association

Today I'd like to talk about the opportunities that exist for dramatic aerospace advances that could simultaneously effect a major upgrading of U.S. defense and space capabilities and a significant improvement in our international trade posture.

In 1985, the United States as a whole suffered a record trade deficit of something in the neighborhood of $150 billion. By way of contrast, the aerospace industry had a positive trade balance of $12.1 billion. Aerospace exports totaled at $18.1 billion; that's an all-time high and a truly remarkable figure when you consider, first, that U.S. manufacturers are bucking foreign trade practices that are often unfair, and second, that the strength of the dollar for most of 1985 worked to the detriment of export sales. All of which underscores the fact that aerospace technology, the principal reason for our outstanding trade performance, plays a vital role in the U.S. economy.

But our foreign competitors are coming after us, as is shown by another statistic: $6 billion in U.S. aerospace imports. That's a record, too. The pace at which our overseas competitors are gaining on us is evident in the fact that the $6 billion is eight times the level of a decade ago. From all reports, our competitors are intensifying their technology development in an effort to garner a still-larger slice of the aerospace pie.

Since aerospace is one of the few sectors of U.S. international trade that enjoys a positive trade balance, we cannot afford any decline in market share. We cannot get complacent about our record level of exports, nor can we settle for continuance of that level; in the interest of the U.S. economy, we must try to increase export sales and the way to do that is to build anew on our traditional strength: technology.

There is—right now—an opportunity to launch a technological surge designed to create a range of future aerospace products of vastly greater technical and economic excellence than the products being built today. This opportunity exists because a number of advanced technologies are reaching maturity or can be brought to early maturity by accelerated research effort.

There appear to be special opportunities in the civil aviation field because studies indicate that the world air transportation system of the 21st century will be considerably different. For example, a NASA report points out that population will continue to grow and more than 75 percent of the growth will be in the developing nations of the Pacific Rim, South America, Asia and Africa. Increasing trade with these nations will involve overwater transportation at very long stage lengths, and that in turn will demand greater speeds—faster-than-sound travel, perhaps Mach 3 or above.

But the high speed airliner of the 21st century will not be, like the Concorde, a premium fare transport restricted to a few routes. Experts feel that advancing technology can reduce operating costs to enable supersonic fares at something close to today's tourist fares—hence, the faster-than-sound airliner will become the dominant mode of long-haul transportation.

For shorter distances, there is need for subsonic aircraft of greater efficiency. The airlines have never totally recovered from the fuel cost escalation of the 1970s and the prime need for the future subsonic transportation system is "affordability"—highly productive, fuel-efficient transports whose much lower operating costs will significantly improve airline profitability. Population shifts to new urban areas will also create a need for new types of transport craft, such as high-speed rotorcraft and high-capacity commuterliners designed for maximum efficiency in short-haul operations.

Thus, in all areas of civil air transportation, and in space and military systems as well, we are presented with technological opportunities that, successfully pursued, could enable us—in the 1990s and the early 21st century—to hurdle the competition and reestablish American dominance of the world aerospace market.

Two years ago, AIA conducted a study —called *Aerospace Technology for the 1990s*—that outlined a plan for revitalizing American competitiveness in the aerospace field through bold and innovative technology thrusts. The AIA study served as input to a later review by a group of government, industry and academic experts assembled by the White House Office of Science and Technology Policy. Released last spring as a statement of national policy, the study report reiterated the caution that the U.S. technological edge has narrowed significantly, called for an aggressive program of advanced technology development, and listed three goals whose attainment could result in U.S. civil and military aircraft of clear-cut superiority. The goals included:

- Technology for an entirely new generation of super-efficient, affordable subsonic aircraft that would advance U.S. military capabilities and capture immense civil market benefits by demonstrating clear superiority to the technology of foreign challengers.
- Technology for sustained supersonic cruise flight that would be applicable to further improvements in military aircraft performance and also permit development of a second generation commercial supersonic transport.
- "Transatmospheric" technology for an aerospace plane that could both take off and land on conventional runways and routinely cruise and maneuver into and out of the atmosphere. Such a capability could make possible an Earth-to-orbit vehicle of airplane-like flexibility or a superspeed passenger transport.
- Since the report was issued, OSTP and industry experts have taken a second look at future space requirements and progress in hypersonic research, and they have advanced an even more exciting possibility. If we are to continue to exploit the economic and scientific potential of space, operational efficiency demands an advanced Space Shuttle or a transatmospheric vehicle—one that could lift far greater payloads and one that could operate, like an airplane, without the elaborate and costly launch complex the current Shuttle needs. Successful development of technologies for

This article is a condensation of Dr. Harr's year-end report to the Aviation/Space Writers Association.

such a craft could make it possible to leapfrog the civil supersonic transport and make the big jump to a hypersonic transport—typically, according to an OSTP description, one that would cruise at 6-7,000 miles per hour at altitudes well above 100,000 feet, moving passengers between any two points on Earth in less than two hours.

Such a transatmospheric vehicle would afford large-scale economic and operational benefits. With launch costs estimated as low as one percent those of the Shuttle, and with payload-to-weight ratio 10 to 15 times greater, the cost of delivering payloads to orbit would drop from thousands of dollars a pound to tens of dollars a pound. The implications for future space operations, particularly commercial development of space, are, of course, stunning. Additionally, initial development of the aerospace plane for civil and military space use would provide a technology base that could sharply reduce the time and cost of developing the companion commercial hypersonic transport. That's a very big factor, because most experts have felt for years that economic feasibility, rather than technical considerations, was the greater barrier to faster-than-sound passenger transportation.

It is significant that the United States has a solid lead in most of the key technologies underlying the objectives of the national aeronautical R&D goals. We have, in the Space Shuttle, the only operational hypersonic vehicle capable of routine flight to orbit and return to an airplane-like Earth landing. That technology offers a big competitive advantage. In addition, NASA, the Department of Defense and industry have for years been researching advancements in hypersonic propulsion, structures, materials and aerodynamics, and significant progress has been made in those areas. The U.S. has also pioneered and is firmly established in technologies that are central to the development of the subsonic aircraft envisioned for tomorrow.

In other words, the opportunity to undertake a technological revolution in aviation and space is "ours," not "theirs." But it is a temporary opportunity, not a permanent option. We can't afford to deliberate endlessly while the competition catches up. We have, to borrow a phrase from Dr. George Keyworth, a "window of opportunity," which must be exploited while we hold the best cards.

At a meeting last November, the AIA Board of Governors endorsed the national aeronautical R&D goals propounded by OSTP and, further, declared a firm industry commitment "to foster and to support a bolder national research and development program, one focused on those key technologies which can ensure that the U.S. maintains a position of aerospace product superiority in the world marketplace."

We in the industry feel that active pursuit of the goals I have outlined constitutes, the "bolder" program the nation needs. While it is extraordinarily challenging, it is nevertheless entirely feasible. It requires no major scientific breakthroughs, although it does demand considerable expansion and acceleration of efforts now under way. And that means additional money for aeronautical/ transatmospheric R&D, beginning right now if we are to pursue the opportunity in timely fashion.

It is, of course, a tight-money time, a time when the national deficit is the overriding consideration in Congressional budget deliberations. But trimming the national deficit is not the only way to improve our economy; of equal importance, in my estimation, is an attack on that other deficit, the international trade deficit. Revitalization of aerospace trade and competitiveness is not a total solution to the nation's overall trade problem, but no other single achievement could do more for U.S. international trade over the long term than firmly reestablishing American dominance of the world aerospace market.

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The purpose of AEROSPACE is to:

Foster understanding of the aerospace industry's role in insuring our national security through design, development and production of advanced weapon systems.

Foster understanding of the aerospace industry's responsibilities in the space exploration program.

Foster understanding of civil aviation as a prime factor in domestic and international travel and trade.

Foster understanding of the aerospace industry's capabilities to apply its techniques of systems analysis and management to solve local and national problems in social and economic fields.

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AEROSPACE HIGHLI

By JAMES J. HAGGERTY

Defense

The Peacekeeper (MX) intercontinental missile, the subject of year-long Congressional debate, lost ground in late year deliberations that resulted in a program reduction from 100 to 50 operational missiles. Meanwhile, the 20-flight test program continued with six successful 1985 flights from Vandenberg Air Force Base, California; the last two, the ninth and 10th of the series, were operational-type silo launches. The flight test program was to include 10 additional silo launches in 1986. The first 10 operational Peacekeepers were slated for deployment at Warren Air Force Base, Wyoming in December 1986.

Major Peacekeeper contractors include Martin Marietta Aerospace (assembly and test); Rockwell Autonetics (guidance and computers); Northrop (inertial guidance system); Morton Thiokol (first stage); Aerojet General (second stage); Hercules Incorporated (third stage); Rockwell Rocketdyne (fourth stage); Avco Textron and General Electric Company (re-entry systems); Westinghouse (missile canister); Boeing (support equipment); TRW Inc. (engineering and technical support); and Honeywell Inc. (guidance and control elements).

Preliminary work continued on the Air Force's single-warhead Small ICBM, which was targeted for full-scale development beginning in late 1986. Among contractors competing for SICBM's three propulsion stages are Aerojet General, Hercules, Morton Thiokol and United Technologies. Competitors for the guidance assignment include Northrop, General Electric, Litton Industries and Honeywell. Bell Aerospace, Boeing, General Dynamics and Martin Marietta Aerospace are studying mobile launch systems.

The fifth of a planned 13 Trident-class nuclear submarines was completed in 1985 and armed with Lockheed-built Trident 1 ballistic missiles. The advanced Trident 2 fleet ballistic missile, 10½ feet longer and almost twice as heavy as its predecessor, was in full-scale engineering development and targeted for deployment at the end of the decade. Trident 2 contractors include Lockheed (prime contractor), Westinghouse (launcher) and General Electric (fire control system).

Planned deployment in Europe of 108 Army/Martin Marietta Pershing 2 ballistic missiles continued on schedule and the Tomahawk GLCM (Ground Launched Cruise Missile) was deployed in five NATO countries; planned installations in a sixth nation—The Netherlands—awaited conclusion of intergovernmental negotiations. Several other versions of the Tomahawk were in development and production by prime contractor General Dynamics and associate contractor McDonnell Douglas. The Air Force proposed to begin production in 1986 of a General Dynamics-developed Advanced Cruise Missile, a follow-on to the USAF's Boeing-built Air Launched Cruise Missile.

In September, the USAF conducted a third test of its air-launched antisatellite (ASAT) interceptor and, for the first time, destroyed a target spacecraft in orbit. Known as the Miniature Vehicle, the ASAT weapon is built by LTV Aerospace; test versions are designed for launch from the McDonnell Douglas F-15 fighter.

Funded at $2.5 billion in Fiscal Year 1986, the Strategic Defense Initiative (SDI) was one of the largest Department of Defense R&D programs, a study and technology development effort intended to explore a variety of space-based, aircraft-based and ground-based options for antiballistic missile defense. In 1985, the Strategic Defense Initiative Organization awarded a large number of contracts for basic research and technology development to industry firms, universities and independent R&D groups. A major award went to Lockheed Missiles & Space Company for development and test of an exoatmospheric (outside the atmosphere) interceptor. Other leading SDI contractors included Boeing Aerospace, TRW, Avco Everett, Rockwell Satellite Division, Teledyne Brown, LTV Aerospace, Hughes Aircraft, General Dynamics and Aerojet General.

In other 1985 missile developments,

- The USAF/Navy Hughes AMRAAM (Advanced Medium Range Air-to-Air Missile) survived extensive Congressional debate and continued as a restructured development program toward a mid-1986 production decision.
- In June, DoD launched development of the Army/Air Force Joint Tactical Missile System (JTACMS) and at year-end

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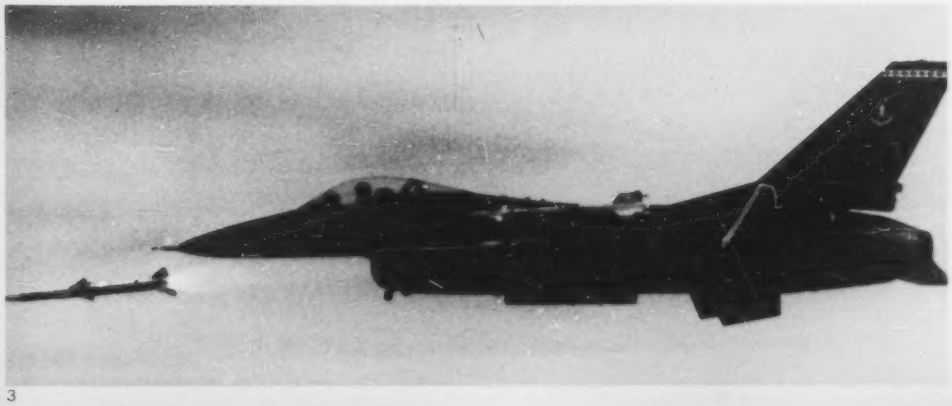

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1. The USAF conducted six more successful tests of the Peacekeeper intercontinental missile, which was scheduled for first operational deployment in December 1986.
2. In full-scale development and targeted for operational service in 1989 was the Navy's Trident 2 fleet ballistic missile. The photo shows a comparison of Trident 2 (left) with the currently operational Trident 1.
3. Flight testing of the AMRAAM (Advanced Medium Range Air-to-Air Missile) continued in 1985.
4. In September, the USAF launched – from an F-15 – an experimental antisatellite weapon that – for the first time – destroyed a target spacecraft in orbit.

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the services were completing review of proposals for contractor selection among competitors Boeing, LTV Aerospace and Martin Marietta.

• The Navy initiated the Outer Air Battle missile program, which includes development of a new long range air-to-air missile and an advanced surface-to-air missile.

• Continuing in development under USAF contract was the LTV Aerospace hypervelocity Missile (HVM) for joint service use as either an air-launched or ground-launched weapon against armor and other "hard" targets; flight demonstrations were planned for late 1987.

• The USMC/Hughes Aircraft Laser Maverick completed a series of fleet-use certification tests.

• The Army was evaluating candidate system concepts for a new Advanced Antitank Weapon System—Medium, intended as a man-portable, longer range replacement for the Dragon field anti-armor missile.

• The Air Force was developing a second generation Short Range Attack Missile—SRAM 2—as a replacement for the aging SRAM 1 on B1B and B-52 bombers.

• In preliminary development was the Army's SADARM (Sense and Destroy Armor) munition, which would be launched from howitzers or the LTV Multiple Launch Rocket System to detect, identify and attack mechanized targets.

The year's highlight in military aircraft development was the start of deliveries of the USAF/Rockwell International B-1B bomber. While test flights continued throughout the year, Rockwell delivered the first production model B-1B to Dyess Air Force Base, Texas in June; two additional bombers were delivered later in the year. Among other military aircraft highlights;

• The Grumman-built, Defense Advanced Research Projects Agency X-29A research airplane, first company tested in December 1984, was turned over to NASA early in 1985 for advanced flight testing. After a summer hiatus for control system modification, the X-29A—which features a foreswept wing—resumed flying in August and by year-end had progressed to supersonic flight tests.

• In October, the USAF's AFTI F-111/MAW (Mission Adaptive Wing) experimental aircraft made its initial flight. The airplane features a variable-camber wing designed to provide a 25-30 percent increase in range and maneuverability. Boeing Military Airplane Company mod-

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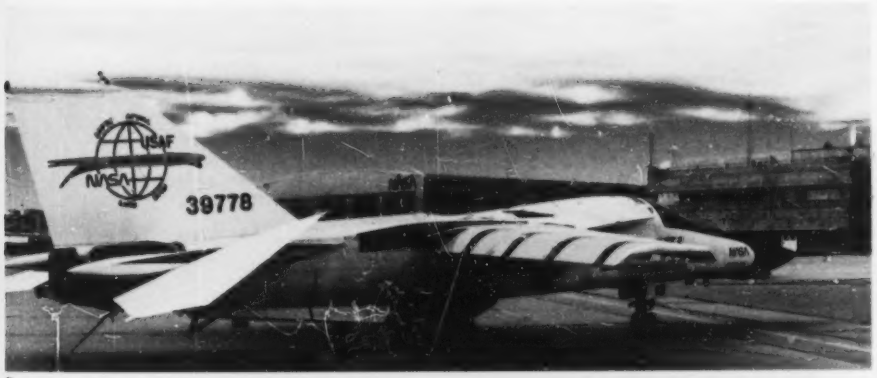

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5. Shown being fitted to a Marine Corps AV-8B Harrier 2, the Laser Maverick surface-to-air missile completed fleet-use certification tests.
6. In June, the USAF took delivery of the first production model B-1B.
7. Undergoing NASA flight test was the Defense Advanced Research Projects Agency's innovative X-29A research airplane, which features a foreswept wing and several other new technologies.
8. The variable-camber AFTI F-111/MAW made its first flight in October.
9. The USAF initiated full-scale development of the C-17A advanced transport, planned for first flight in 1990.
10. Preliminary design of the V-22 joint service tilt-rotor aircraft was completed.

ified the wing to incorporate variable camber, which involves computer-directed changes of the fore and aft curvature of the airfoil to achieve maximum aerodynamic efficiency for any given flight condition.

• At year-end, Douglas Aircraft Company received a full-scale development contract for the C-17A advanced Air Force transport. Assembly of the first airplane was scheduled to start in 1987, with first flight in 1990. The USAF long range plan called for production of 210 C-17s through 1998.

• Flight demonstrations of the first C-5B Air Force transport, built by Lockheed-Georgia Company, were completed in November and the airplane was delivered to Altus Air Force Base, Oklahoma in December. The program involves production of 50 C-5Bs, eight more to be delivered in 1986.

• The Air Force requested proposals from seven airframe manufacturers for a three-year demonstration/validation of the Advanced Tactical Fighter, planned for first operational service in 1995.

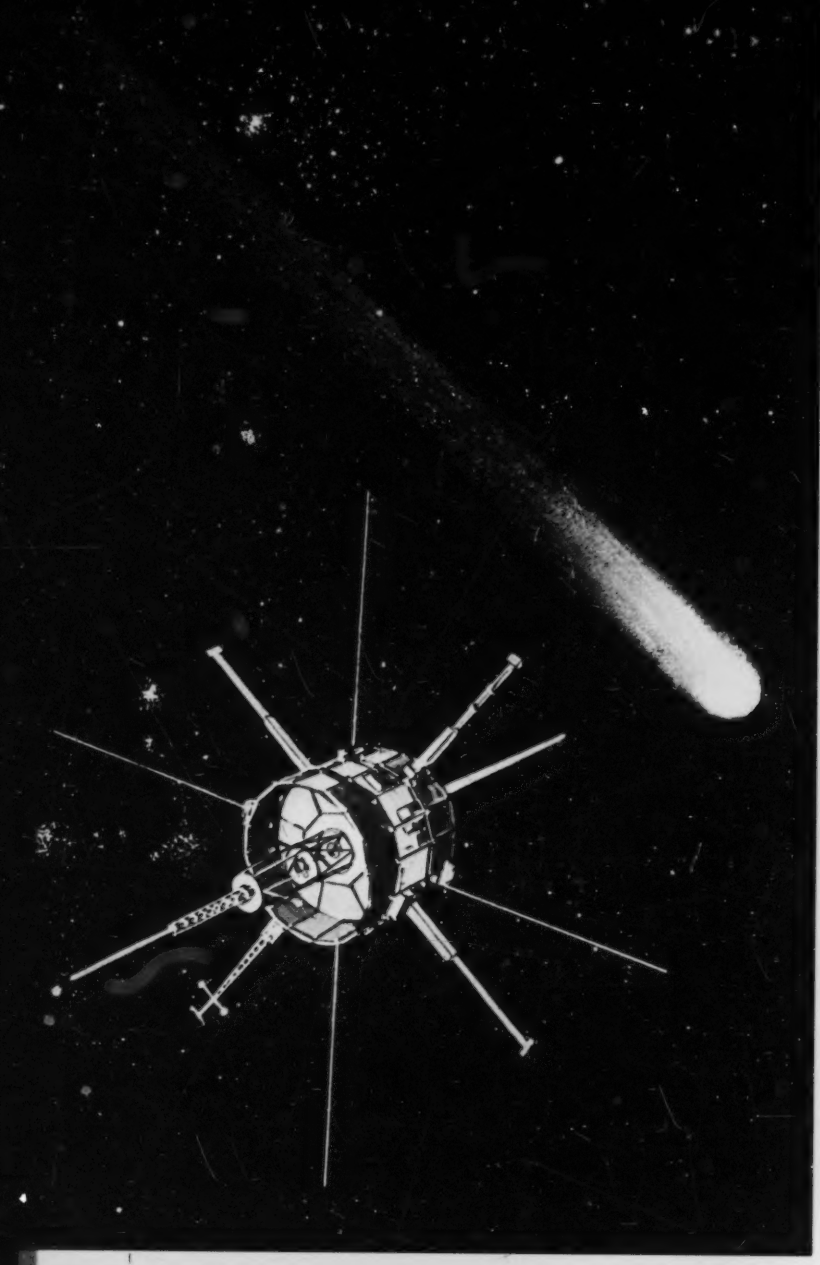
• In November, Lockheed-California Company delivered to the Navy the first two of four upgraded S-3B Viking antisubmarine warfare aircraft. The planes will undergo a nine-month test and evaluation program, following which the Navy will decide whether to upgrade some or all of the 160 S-3A's in service.

• The first of four Boeing-built USAF EC-18B ARIA (Advanced Range Instrumented Aircraft) airborne tracking stations made its first flight in March and went into USAF service in August. The aircraft are modified Boeing 707-320s.

• The Bell Helicopter Textron/Boeing Vertol team completed preliminary design of the V-22 Osprey Joint Services Vertical Lift Aircraft. Late in December, the Navy announced selection of Allison Gas Turbine Division of General Motors Corporation for full scale development of the engine for the tilt-rotor V-22. The Osprey was scheduled for full-scale development beginning in 1986 and first flight in 1988.

• The Marine Corps/McDonnell Douglas AV-8B Harrier 2 V/STOL fighter completed operational evaluation testing and the first units were delivered to the USMC.

• The Army continued preliminary development of the LHX (Light Helicopter Experimental) and planned full-scale development beginning in 1987. Competing contractor teams include Boeing Vertol/Sikorsky and Bell Helicopter Textron/McDonnell Douglas.



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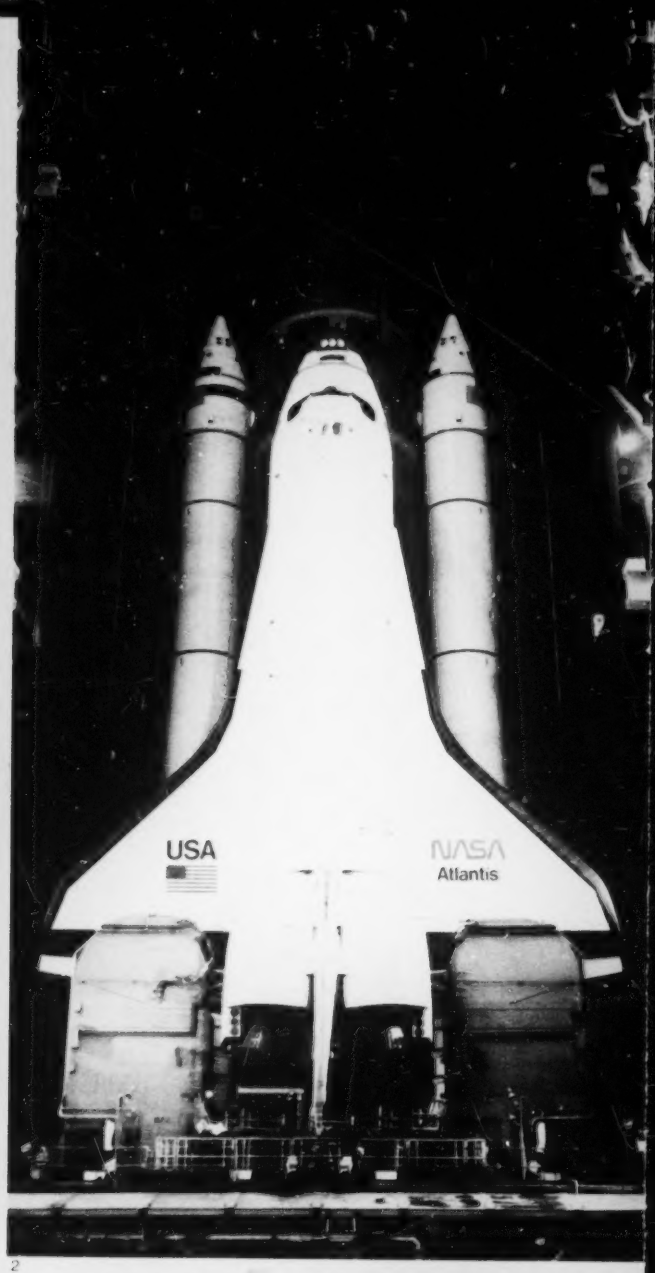

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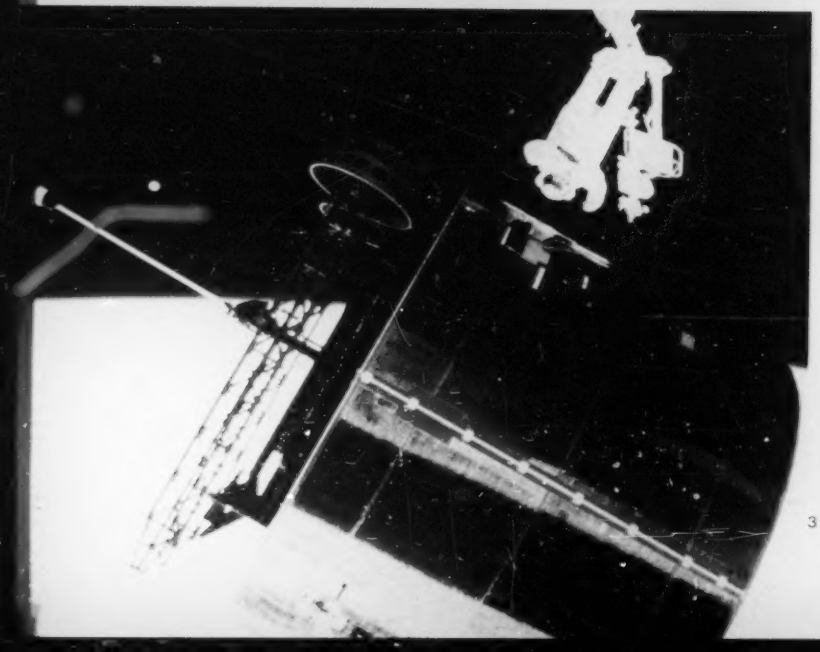

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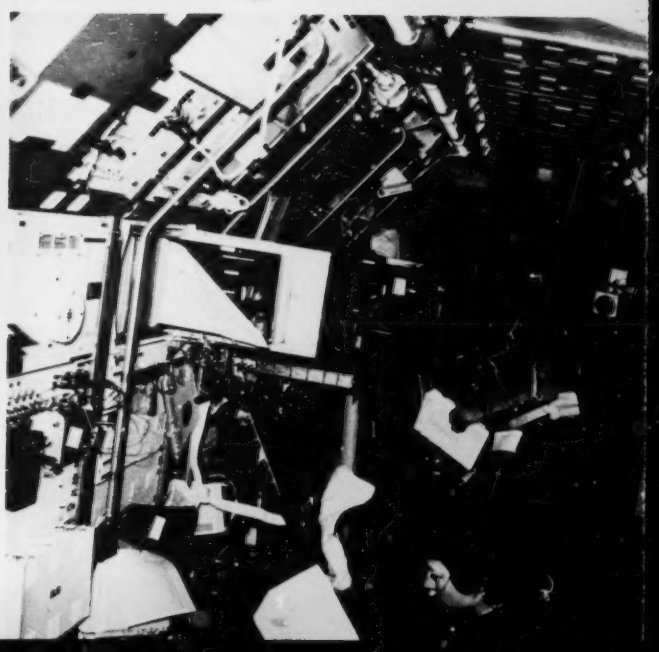
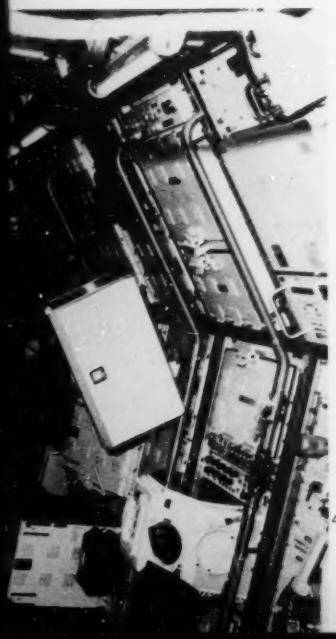


1. In September, NASA's International Cometary Explorer became the first spacecraft to intercept a comet when it passed within 5,000 miles of Comet Giacobini-Zinner's nucleus.
2. The fourth Orbiter, *Atlantis*, joined the Space Shuttle fleet in April and flew its first two missions in October and November.
3. The crew of Shuttle Mission 51-I (September) captured, repaired and released a Leasat communications satellite earlier deposited in a useless orbit. In the photo, astronaut James van Hoften gives the repaired Leasat a departing shove.
4. Interior view of the Spacelab materials processing laboratory on the West German D1 mission (November); in photo are astronaut Bonnie Dunbar (foreground) and German payload specialist Reinhard Furrer.



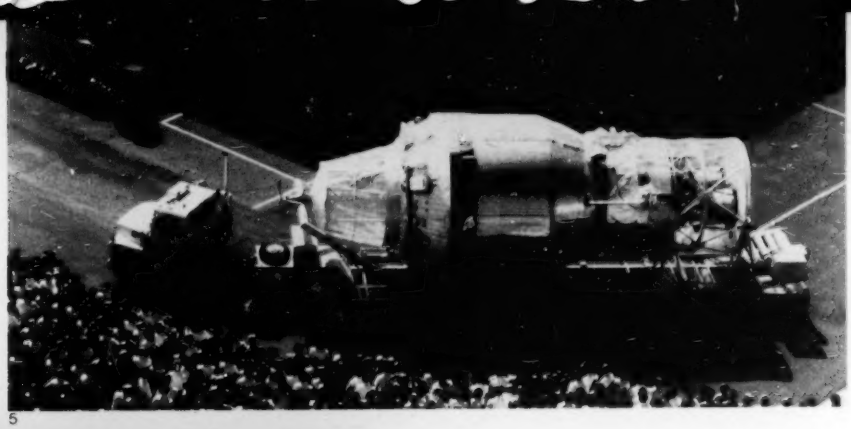
The highlight of 1985 in space came on September 11 when NASA's International Cometary Explorer (ICE) became the first spacecraft in history to intercept a comet. ICE flew through the tail of Comet Giacobini-Zinner about 5,000 miles from the comet's nucleus and apparently came through undamaged. Launched in 1978, ICE was originally not intended for comet study (its earlier name was International Sun/Earth Explorer-3), hence has no imaging equipment, but its sensors provided valuable data on cometary dust, magnetic fields and the interaction of the comet with the solar wind. At year-end, ICE was on an orbit that would position it about 20 million miles from Comet Halley in March 1986, where it would provide solar wind information that will complement the findings of the international Halley-watching fleet of close-encounter spacecraft.

Although there is no U.S. spacecraft in the Halley-bound fleet, NASA will be well represented in the international data gathering operation by observations from four already orbiting spacecraft, including ICE. The others are Pioneer Venus, which began ultraviolet observations in December and will continue into March, and the Solar Max and International Ultraviolet Explorer satellites, which will train their instruments on Halley in March. In addition, a March mission of a Shuttle-based three-telescope observatory called Astro will be devoted to Halley viewing, as will a Spartan free-flying satellite that will be Shuttle-launched and retrieved on the same mission.

In 1985, NASA successfully operated nine Space Shuttle flights. The first (51-C, January) was a classified Department of Defense mission in which the USAF/Boeing Inertial Upper Stage returned to service and performed perfectly, boosting a DoD satellite to synchronous orbit. The modified, updated McDonnell Douglas PAM-D upper stage also performed flawlessly in its service re-introduction, boosting three commercial communications satellites on Mission 51-G in June. Among other Shuttle highlights of 1985 were the first officially-operational mission of the Spacelab, Spacelab 3, in which astronauts of Mission 51-B (May) conducted extensive materials processing experiments; the first deployment/retrieval of a Spartan free-flying satellite (51-G, June); acquisition of important astronomical and other scientific information on the Spacelab 2 mission (51-F, August); the recapture and repair of an errant Hughes Leasat communications satellite (51-I, September); introduction to operational service of the fourth Shuttle Orbiter, *Atlantis*, (51-J, October); the third Spacelab mission of the year, the West German-dedicated D1 flight carrying 76 materials processing experiments (61-A, November); and the first Shuttle-based experiments in erecting structures in orbit (61-B, November-December). The nine missions marked the most active year for the Space Shuttle, but NASA was planning 15 flights for 1986. Principal Shuttle contractors are Rockwell International (prime contractor and Orbiter manufacturer); Morton Thiokol Corporation (solid rocket boosters); and Martin Marietta Aerospace (external fuel tank).

In other 1985 developments on the space scene,

- In March, General Electric's Valley Forge Space Center was awarded a contract for development of the NASA Upper Atmosphere Research Satellite, to be launched in 1989.
- In April, NASA awarded Phase B space station preliminary design and definition studies to some 80 contractors organized into eight teams; Phase B was scheduled for completion in January 1987.
- The Landsat Earth survey remote sensing satellite system, initially operated by NASA, later by the National Oceanic and Atmospheric Administration, was "privatized" with its September transfer to EOSAT, a joint venture of RCA Corporation and Hughes Aircraft.
- Also in September, General Dynamics delivered to NASA the first Shuttle/Centaur upper stage; Centaurs will be used in launching the Galileo (Jupiter) and Ulysses (Solar Polar) missions in May 1986.
- In November, NASA issued requests for proposals for design, development and manufacture of the Orbital Maneuvering Vehicle (OMV), an orbital tug that will extend the range of the Space Shuttle by about 1,000 miles. LTV Aerospace



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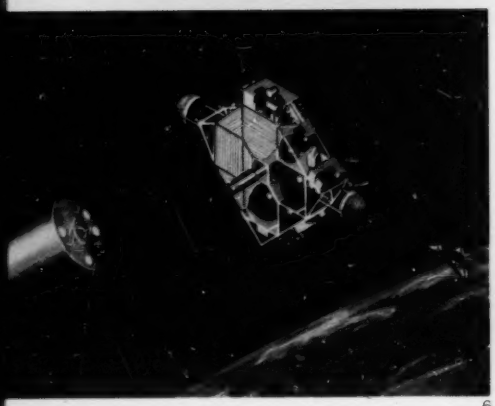

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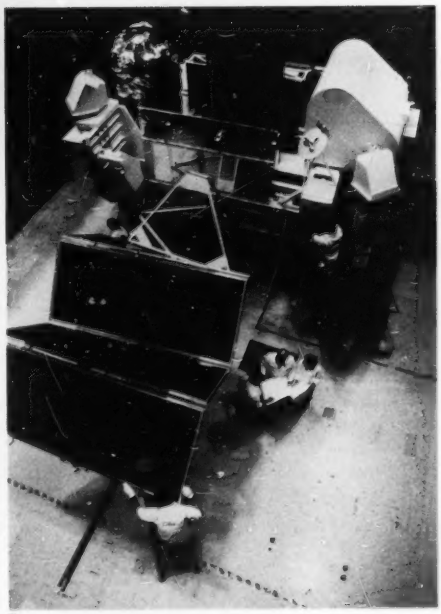

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5. In August, the first Shuttle/Centaur upper stage was rolled out of the General Dynamics San Diego plant.

6. Artist's concept of the Orbital Maneuvering Vehicle (OMV), a space tug that will supplement and extend the range of the Space Shuttle. NASA requested proposals for OMV design and development in November.

7. In development for 1988 launch is the Gamma Ray Observatory, intended for a comprehensive investigation of gamma ray energy and sources; in photo, TRW's full-scale mockup.

and Defense, Martin Marietta Aerospace and TRW Inc. are the competitors.

At year-end, the Voyager 2 spacecraft was approaching Uranus to take the first closeup images of the seventh planet in January 1986 and kick off what promised to be an exceptionally active year in space science. Among key scientific missions scheduled for 1986 are:

- Galileo, to be Shuttle-launched in May, a two-element—orbiter and atmospheric probe—spacecraft for advanced exploration of Jupiter. Jet Propulsion Laboratory built the orbiter, Hughes Aircraft and General Electric teamed on development of the probe.
- Ulysses, which will depart in May on a five-year jaunt through interplanetary space and around the poles of the Sun, investigating areas never before visited by spacecraft. The Shuttle-launched mission is a joint effort of NASA and the European Space Agency.
- Hubble Space Telescope, a large observatory planned for October Shuttle launch, potentially the most important advance in astronomy since the invention of the telescope. Lockheed Missiles & Space Company is prime spacecraft contractor, Perkin-Elmer Corporation is telescope assembly contractor.

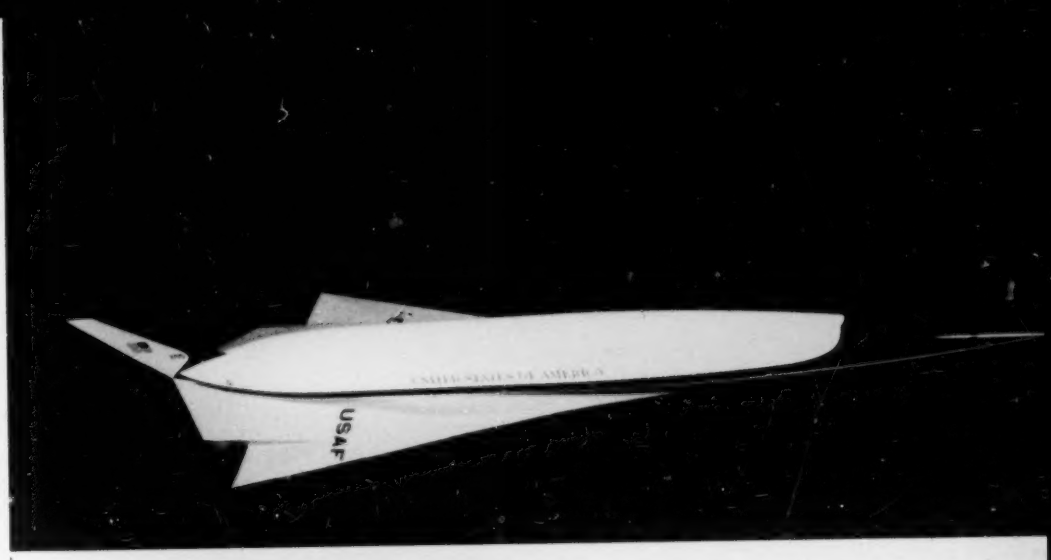
Among other NASA development programs active in 1985 were:

- Magellan, formerly known as the Venus Radar Mapper, a mission designed to penetrate Venus' cloud cover and map—in greater detail than was earlier accomplished—90 percent of the planet's surface. Magellan is scheduled for launch in April 1988 and Venus arrival in July 1989. Contractors include Martin Marietta Aerospace (spacecraft) and Hughes Aircraft (imaging radar).
- Mars Observer, which will map Mars, investigate the Martian climate and explore the elemental/mineralogical characteristics of the planet's surface. It is targeted for launch in August 1990 and arrival at Mars a year later. Several companies are competing for the spacecraft and upper stage booster; selections are expected early in 1986.
- AXAF (Advanced X-ray Astrophysics Facility), intended to observe x-ray sources in the universe 100 times weaker than those investigated by predecessor x-ray observatories. AXAF is planned for orbital service in the early 1990s; TRW Inc. and Lockheed Missile & Space Company are working on system definition contracts.
- Gamma Ray Observatory, being developed by TRW, planned for launch in 1988 to study how gamma rays are produced and where they come from.

Military space activity continued at the fast pace evidenced in recent years, but details are classified for the most part. Aside from the Strategic Defense Initiative (see Defense, page 2), the Department of Defense was generally replacing existing communications, weather and intelligence-gathering satellites with more advanced systems, and developing advanced capabilities in missile attack warning, communications security and spacecraft survivability. In addition, DoD was preparing for mid-year 1986 introduction of the Space Shuttle to military operations from Vandenberg Air Force Base, California. Among unclassified military space developments of 1985:

- DoD was operating an interim, 10-satellite Navstar Global Positioning System for precise location of air, sea and land vehicles. Rockwell International was developing advanced versions of the Navstar for an operational 18-satellite network that will replace the interim system beginning in 1988.
- DoD selected the General Dynamics Centaur as the upper stage booster for the Milstar extra-secure, highly survivable EHF (Extremely High Frequency) military communications satellite being developed by Lockheed Missiles & Space Company.
- With Martin Marietta Aerospace as prime contractor, the Air Force was developing a Complementary Expendable Launch Vehicle (CELV) as an alternative to Shuttle launching for certain military payloads. Capable of delivering 10,000 pounds to synchronous orbit, the first CELV was planned for launch in October 1988.
- DoD was developing a scientific/tactical oceanographic survey system known as the Navy Remote Ocean Sensing System for launch in the late 1980s.

1. Air Force concept of a 1990s aerospace plane, technology for which could be adapted to a commercial hypersonic transport.
2. Among advanced turboprop developments was the General Electric unducted fan, or UDF, shown being readied for ground test at GE's Peebles (Ohio) facility.
3. The Sikorsky-built experimental X-wing aircraft was being readied for initial flight in the latter part of 1986.



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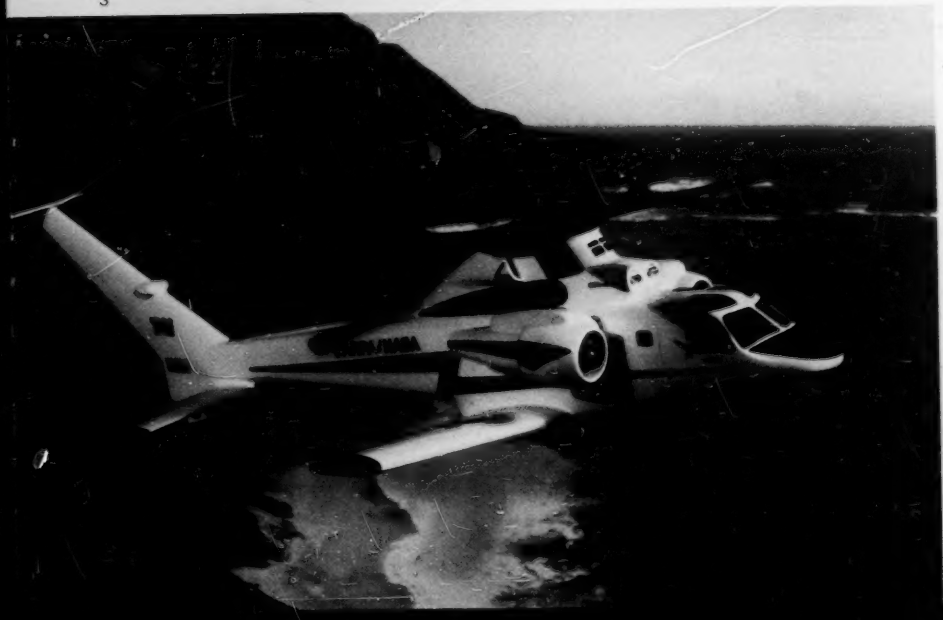

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Civil Aviation

Development of technology for a "transatmospheric" aerospace plane, one version of which might be a hypersonic civil transport, was listed as a national research goal in an April policy statement issued by the White House Office of Science and Technology Policy. Prepared by a government/industry/academic Aeronautical Policy Review Committee, the statement—*National Aeronautical R&D Goals*—also proposed advancing technologies for a 1990s generation of extra-efficient civil and military subsonic aircraft and laying the groundwork for a second generation supersonic transport. OSTP and the committee took a second look at progress in high speed flight and, in November, OSTP suggested the possibility of leapfrogging the supersonic transport and making the big leap to a hypersonic transport, typically one that could fly at 6-7,000 miles per hour and move passengers between any two points on Earth in less than two hours (see *Window of Opportunity*, inside front cover).

In 1985, NASA was actively engaged in advancing technology for the subsonic goal toward commercial transports, military airlifters and high-speed rotorcraft that will burn substantially less fuel than their current counterparts, have dramatically lower operating costs and be producible—hence salable—at lower cost. NASA was developing technology in four general areas: drag-reducing laminar flow control; structures and structural materials; advanced flight controls; and propulsion systems, including highly advanced turbofan engines and new turboprop systems that could power 1990s transports at jetliner speed with fuel savings of as much as 30 percent.

The latter effort—the Advanced Turboprop Program—neared flight test status after several years of laboratory and wind tunnel investigation. NASA was readying for flight a system that includes a nine-foot-diameter swept-tip propfan assembly developed by Hamilton Standard Division of United Technologies; a

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drive system consisting of a modified existing engine and a new gearbox developed by Allison Gas Turbine Division of General Motors; and a new-design engine nacelle built by Rohr Industries, Inc. The whole assembly will be mounted on the wing of a Gulfstream 2 light transport being modified by Lockheed-Georgia Company for test flights beginning late this year. In another advanced turboprop investigation, NASA was ground testing a unique type of propfan known as the unducted fan or UDF; developed by General Electric Company, it is a pusher-type counter-rotation system with two rows of eight highly swept blades.

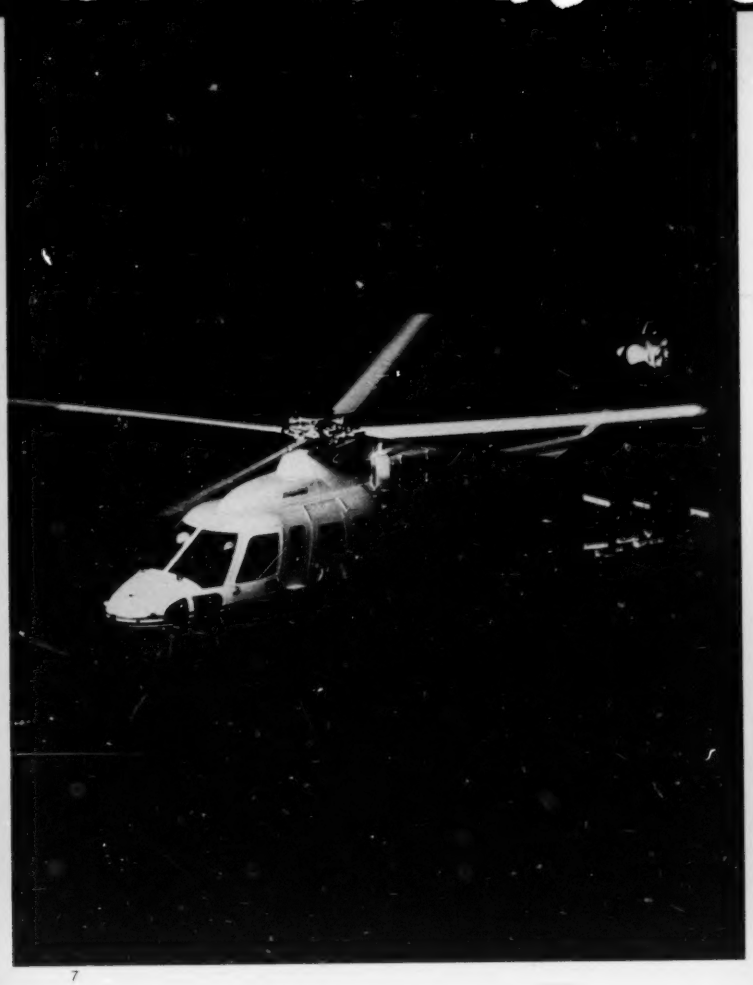
In rotary wing research, NASA and the Defense Advanced Research Projects Agency continued preliminary work on the Sikorsky-built X-wing, a modification of the Rotor Systems Research Aircraft. A promising concept for future short-haul commercial transport operations, the X-wing operates as a helicopter for takeoff, hovering and low speed flight, then, its rotor stopped and locked in place to provide fixed-wing lift, it flies as an airplane at speeds approaching 500 miles per hour. NASA planned to start test flights in the latter part of 1986.

NASA also continued flight testing of the XV-15 Tilt Rotor Research Aircraft, built by Bell Helicopter Textron, developing data toward future use of the tilt-rotor aircraft in civil transport operations and additionally acquiring information in support of the military V-22 tilt-rotor development (see Defense).

In another research program that has both civil and military potential, NASA announced in November the award of a contract to Rockwell International's North American Aircraft Operations for preliminary design of a pivoting wing for the NASA/Navy oblique wing research program. Fitted to an F-8 fuselage, the wing will be capable of pivoting up to 60 degrees in flight; the concept offers greater aerodynamic efficiency at supersonic speed while retaining good efficiency and flying qualities at lower speed. Flight tests are planned for 1988.

For civil aircraft manufacturers, 1985 was a rebound year in which sales, lagging in recent years, gained 27 percent to a total of $13.6 billion. The gain was due for the most part to a 50 percent increase in unit deliveries of commercial transports—from 185 in 1984 to 277 in 1985. Transport sales amounted to $8.5 billion, up from $5.7 billion. Jetliner backlog at year-end was $17.1 billion, the highest since 1980. Transports in production included the Boeing 737, 747, 757 and 767, the McDonnell Douglas MD-80 series and DC-10, and the Lockheed L-100.

McDonnell Douglas launched a new transport development, the trijet MD-11,



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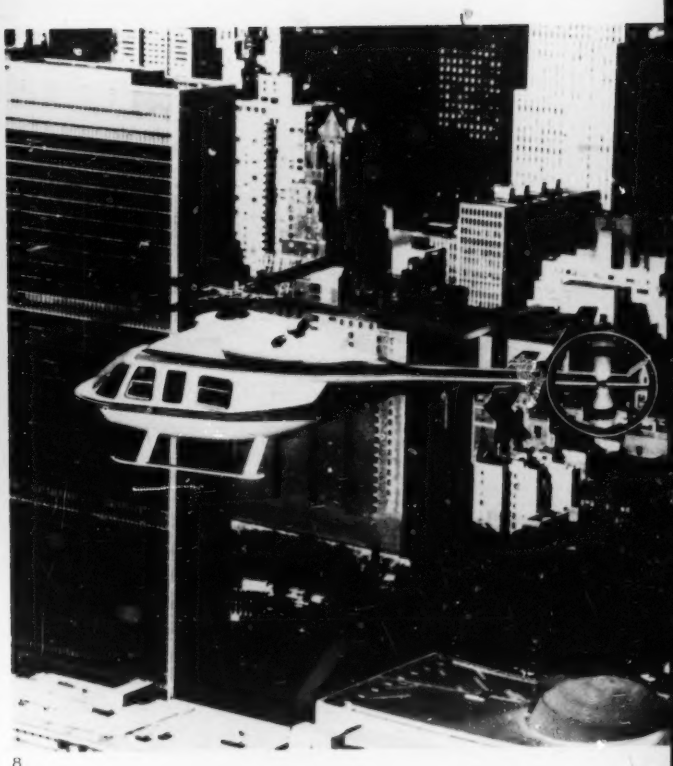

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which features winglets, design changes to reduce weight and drag, and greater fuel efficiency than the DC-10. McDonnell Douglas also began fabricating subassemblies for the new MD-87, a short, 130-passenger version of the MD-80 family; first deliveries—to Finnair and Austrian Airlines—were targeted for September and October 1987.

Boeing Commercial Airplane Company announced an aerodynamically-improved, longer range 747-400, which will feature six-foot winglets, advanced cockpit systems and a horizontal tail tank carrying another 3,000 gallons of fuel.

The decline in sales of general aviation aircraft continued. General aviation manufacturers delivered 2,100 airplanes, 338 fewer than in 1984, and sales were down by some $300 million to a 1985 level of $1.4 billion. The sharp degree of decline is underlined by the fact that sales in 1985 amounted to less than 50 percent of those recorded in 1981.

The rotary wing segment of the industry produced fewer civil helicopters (down 27 to 339) but dollar value was higher than in 1984 (up $41 million to $371 million). Transport-type helicopters in production included the Bell Helicopter Textron Model 22, the 44-passenger Boeing Vertol Model 234, and the Sikorsky S-76; in October, Sikorsky received certification for the S-76B, a new version powered by Pratt & Whitney Canada PT6B-36 engines. Also in production, by McDonnell Douglas Helicopter Company, were several variations of the Model 500 civil helicopter; the company is the former Hughes Helicopters, Inc., purchased by McDonnell Douglas in 1984 and renamed in August 1985. Bell was conducting preproduction testing of five Model 400 TwinRangers, which will be manufactured at the company's Canadian facility in Montreal.

4. NASA and the Navy planned flight tests starting in 1988 to investigate the oblique wing concept at supersonic speeds.
5. McDonnell Douglas launched a new trijet transport development, the MD-11.
6. Boeing announced an aerodynamically-improved, longer range 747-400.
7. Production started on the newly certified Sikorsky S-76B.
8. In preproduction test status was Bell Helicopter Textron's Model 400 TwinRagner.

AEROSPACE '85

In 1985, aerospace industry sales increased by 15 percent over 1984 in current dollars and by 10 percent in inflation-adjusted constant dollars; the real sales level was the industry's highest since 1969. Backlog and profits reached record levels and employment increased substantially.

Here is a summary, based on preliminary data, of the aerospace year 1985:

Sales. Total industry sales amounted to $96.2 billion, up from $83.5 billion in 1984. The increase was compounded of substantial gains in all categories; the greatest proportional gain—more than 27 percent—was in civil aircraft, an area that had been lagging in recent years.

Military aircraft sales, as usual, topped the major categories; sales amounted to $35.2 billion, up from $31.2 billion in the previous year. Space sales, civil and military combined, placed second and continued their sharp ascent, up $2.8 billion to $19.1 billion. Civil aircraft sales totaled $13.6 billion, up from $10.7 billion, and missile activity, at $12.3 billion, was up $1 billion. The industry additionally recorded sales of $16 billion in a new "related products and services" category that includes aerospace-related systems and ground equipment not directly associated with the major categories plus sales of non-aerospace products manufactured in aerospace facilities.

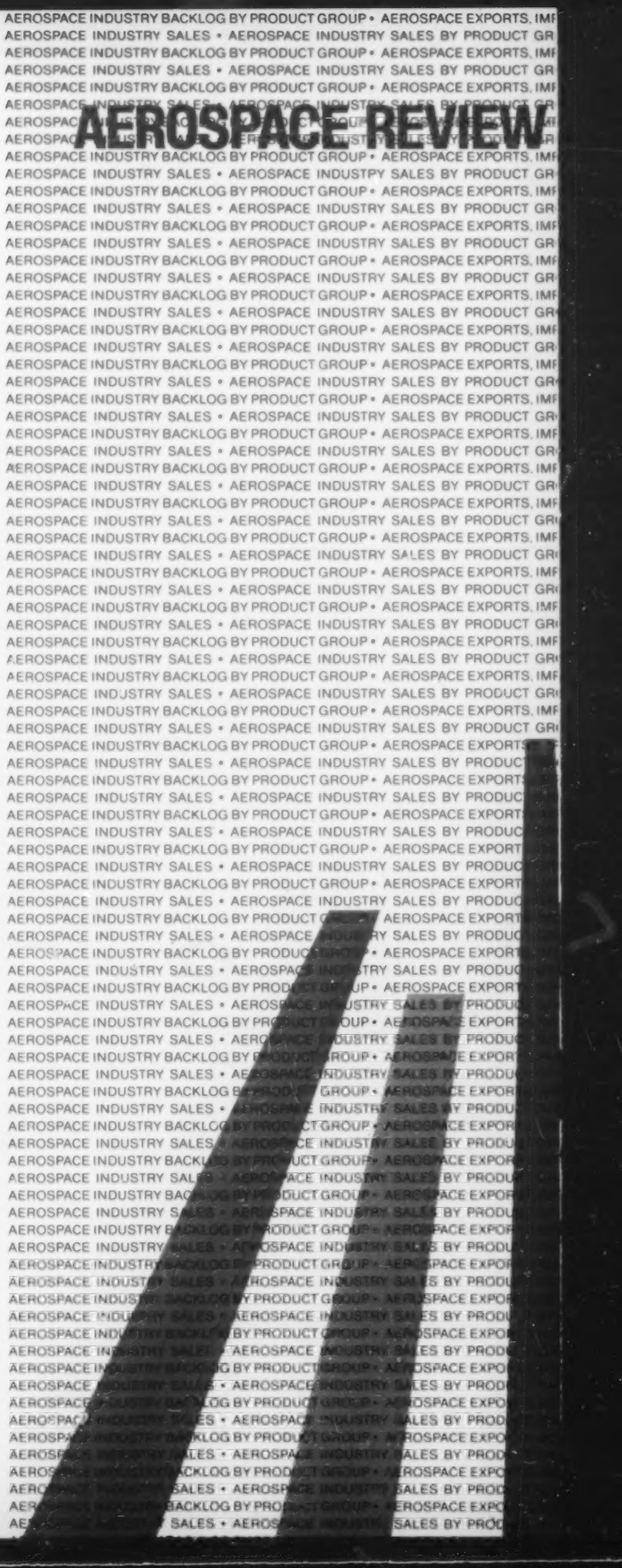
Backlog. Orders on the industry's books at year-end 1985 totaled $127.3 billion, an all-time high that represents a gain of almost $7 billion during the year. New orders received during 1985 amounted to $92.8 billion, down slightly from 1984's $93.2 billion.

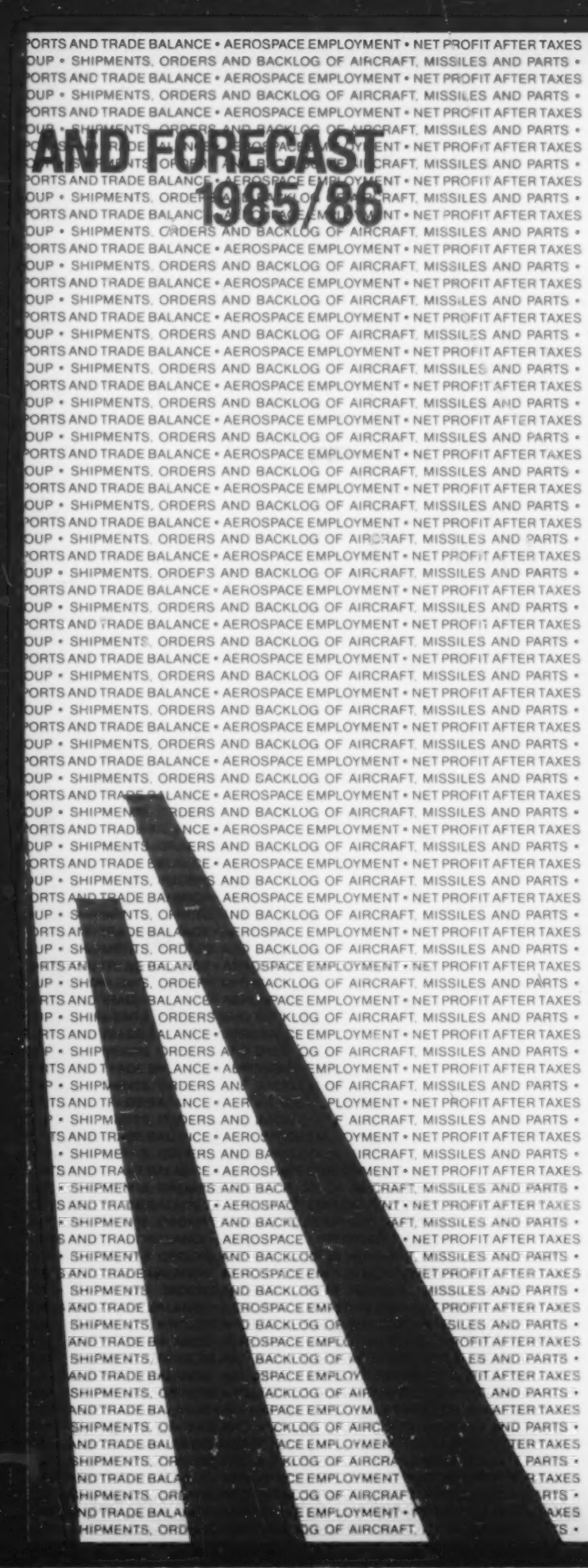
International Trade. After reaching a five-year low of $10.3 billion in 1984, the aerospace trade balance rebounded in 1985 to $12.1 billion, up 18 percent. Aerospace exports increased 21 percent to a new record of $18.1 billion, a remarkable performance in view of intensifying foreign competition and the fact that the U.S. dollar remained strong for most of the year and thus tended to restrain U.S. export volume. On the other side of the coin, stronger competition from abroad was reflected in the aerospace imports figure—$6 billion, also a record. In both exports and imports, the major influences in the record-setting sales levels were large gains in sales of commercial transport aircraft.

Earnings. The aerospace industry recorded an all-time high profit of almost $4 billion, which compares with $3.6 billion in 1984. Measured as a percentage of sales, the profit rate was 4.2 percent, slightly above the four percent average for all U.S. manufacturing corporations.

Plant and Equipment. Aerospace industry expenditures for new plant and equipment amounted to $3.7 billion, a four percent increase in current dollars but exactly equal to the 1984 level in constant dollars. For 1986, expenditures are projected to increase to $4.2 billion.

Employment. Aerospace employment rose by seven percent to a year-end level of 1,337,000, the highest since 1968. Employment was expected to increase again in 1986, but at a modest rate of two percent to a year-end total of 1,365,000.


AEROSPACE REVIEW
AEROSPACE INDUSTRY BACKLOG BY PRODUCT GROUP • AEROSPACE EXPORTS, IMF
AEROSPACE INDUSTRY SALES • AEROSPACE INDUSTRY SALES BY PRODUCT GR



FORECAST

Aerospace Industries Association estimates that total sales in 1986 will reach $103.2 billion, a gain of approximately $7 billion and an increase of 2.4 percent in real terms.

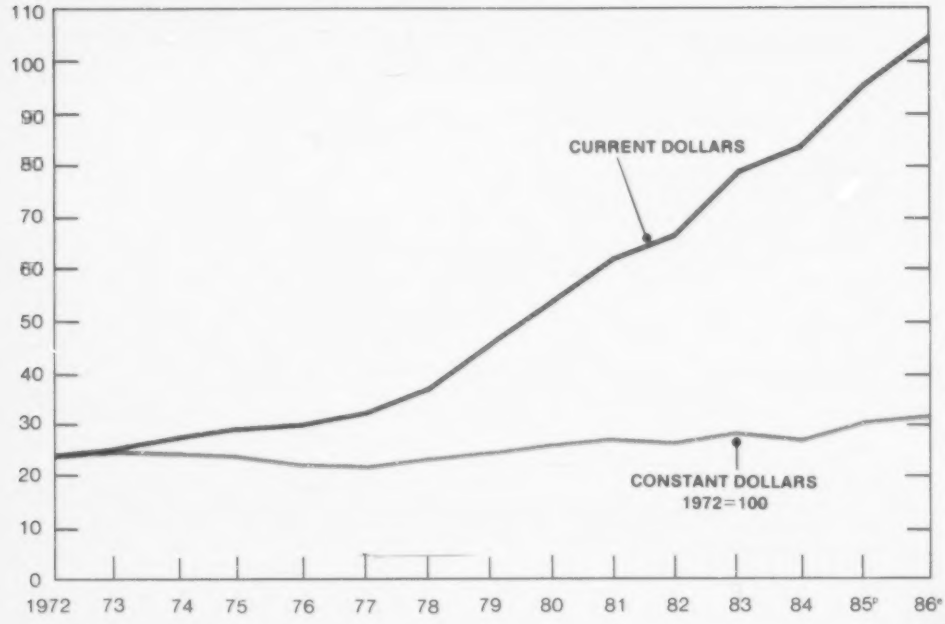
Defense. AIA projects that sales of aerospace products and services to the Department of Defense will be on the order of $56 billion in 1986; that would represent an increase of slightly more than six percent. On the basis of orders already on the books, gains are expected in all categories—aircraft, engines and parts, missiles, and space. The record backlog indicates that defense production and R&D activity will continue at high levels over the next two to three years. Beyond that, AIA is making no projections, due to a number of uncertainties regarding the future of the Reagan Administration's defense buildup program, in particular a budget-balancing amendment passed by the Congress in late 1985; that law would appear to have severe impact on defense appropriations, but the degree of impact cannot yet be measured.

Space. In 1985, space sales—civil and military combined—grew by 17 percent on top of a similar increase in the preceding year and a very big jump of more than 30 percent in 1983. Thus, space has been the most rapidly expanding segment of the aerospace industry's business. AIA estimates, on the basis of backlog, that space sales will top the $20 billion level for the first time in 1986, but the gain will be only six percent. Here again there are no solid indicators on which to base a long term projection, due to uncertainty as to how deficit reduction measures on Capitol Hill will impact military space—the fastest growing element—and NASA's space station plans.

Civil Aircraft. After reaching a record level in 1981, sales of civil aircraft dropped off sharply in the years 1982-84 but increased substantially in 1985, due to the improving financial health of the world's airlines and an attendant resumption of reequipment programs. AIA sees further increases in transport sales for 1986, a gain of more than $2 billion to a level of $10.6 billion. Sales of civil helicopters, which have been declining throughout the 1980s, are projected to rebound strongly. Sales of business jets and general aviation aircraft, however, are expected to remain at something close to 1985 levels. Overall, AIA predicts a real civil aircraft sales increase of eight percent for 1986. The high backlog of orders for commercial transports suggests ongoing production growth for near-future years. In addition, the favorable balance of trade in civil aircraft should continue because the backlog of foreign orders as a percentage of total orders is at its highest level since 1980.

AEROSPACE INDUSTRY SALES

(Billions of Dollars)

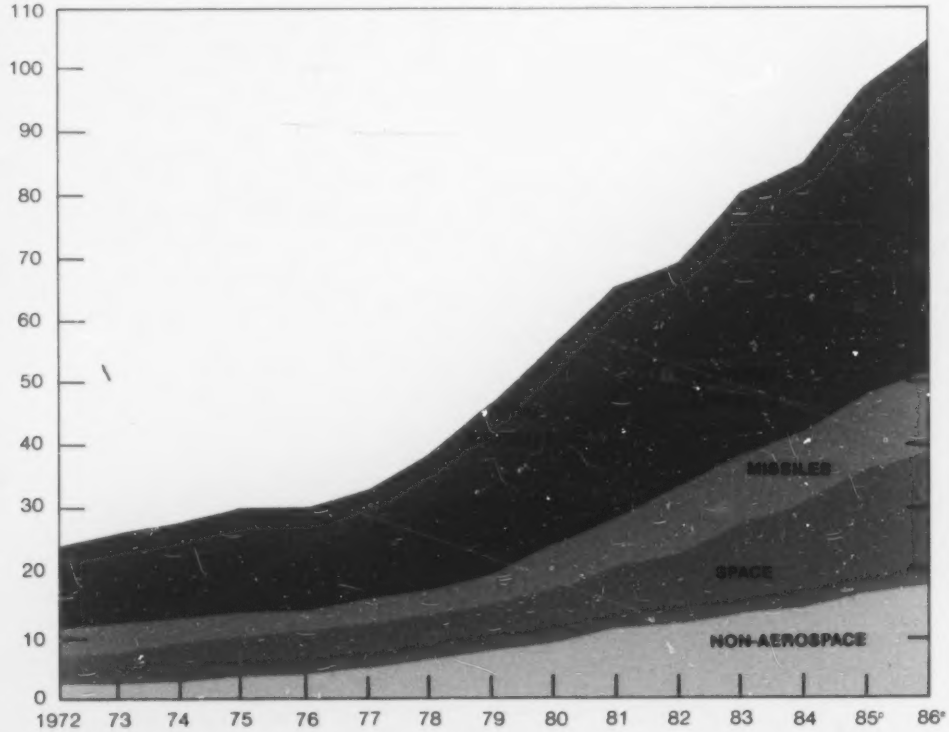


Source: Aerospace Industries Association
e Estimate
p Preliminary

The aerospace industry's 1985 total sales of $96.2 billion included $80.2 billion in aerospace products and services and $16 billion in related products and services. As usual, the Department of Defense predominates in a breakdown of aerospace sales by customer. DoD sales amounted to $52.7 billion, 65 percent of the total; sales to NASA and other government agencies totaled $6.3 billion. Non-government sales of aerospace products were $21.2 billion. For 1986, Aerospace Industries Association estimates total sales at $103.2 billion with $86 billion of it—about 83 percent—in aerospace products and services.

AEROSPACE INDUSTRY SALES BY PRODUCT GROUP

(Billions of Constant Dollars)

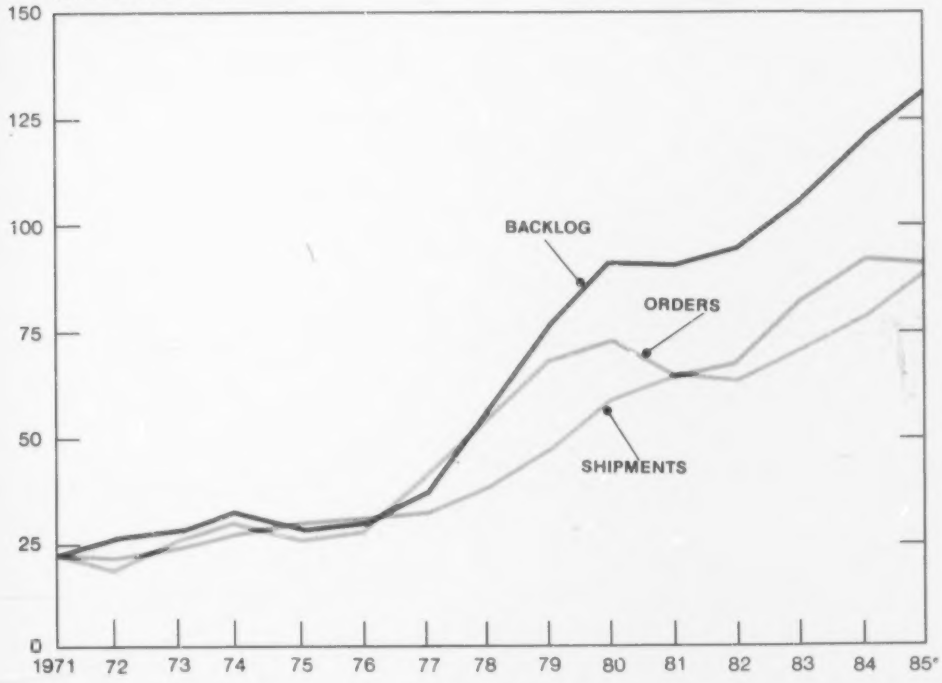


Source: Aerospace Industries Association
p Preliminary
e Estimate

As is customary, production of aircraft represented the largest single element of the 1985 sales volume—slightly more than half of the total. Sales of military aircraft, at $35.2 billion, accounted for nearly three-quarters (72 percent) of all aircraft sales. Civil aircraft sales, depressed for the prior three years, rebounded to $13.6 billion, a gain of more than 27 percent that was the largest proportional increase among major sales categories. Space-related business increased by 17 percent to $19.1 billion and missile fabrication increased by eight percent to $12.3 billion. The "related products" category—items that do not fit into the other major categories—is a new statistical grouping for which no prior year comparison is available. For 1986, AIA projects moderate gains in all categories, led by a 13 percent increase in civil aircraft sales.

SHIPMENTS, ORDERS AND BACKLOG OF AIRCRAFT, MISSILES AND PARTS

(Millions of Dollars)



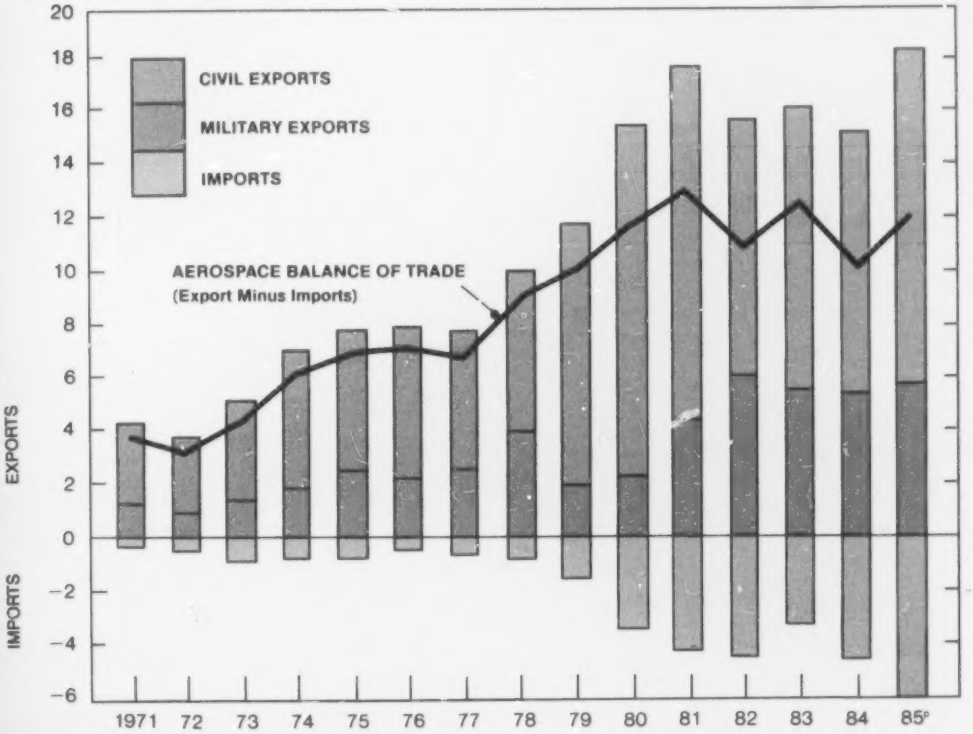
Source: Aerospace Industries Association, based on data from the Bureau of the Census, Department of Commerce

e Estimate

The aerospace industry's backlog at year-end 1985 was $127 billion, according to estimates based on Bureau of the Census data; that represented a gain of almost $7 billion, or close to six percent. The Census figure, however, does not include orders for non-aerospace products and services and such backlog data is not available from other sources. Orders received during 1985 for aerospace products —$92.8 billion—were down slightly from 1984; shipments during the year—$86 billion—were up almost nine billion over the previous year's level.

AEROSPACE EXPORTS, IMPORTS AND TRADE BALANCE

(Billions of Dollars)



Source: Aerospace Industries Association

p Preliminary

The 1985 aerospace export volume increased 21 percent over the depressed level of 1984 to a new record $18.1 billion. Civil exports amounted to $12.5 billion and military exports totaled $5.6 billion. The increase in export sales was due primarily to a significant gain in civil exports, in particular commercial transport aircraft; military exports increased only slightly.

Aerospace imports similarly reached a new record level—$6 billion; the increase over 1984 was almost 30 percent. The aerospace balance of trade was $12.1 billion, up substantially over 1984 but well below the 1981 record level of $13.1 billion.

CIVIL AIRCRAFT SHIPMENTS

Calendar Years 1969-1986

	NUMBER OF AIRCRAFT SHIPPED				VALUE (Millions of Dollars)			
Year	TOTAL	Commercial Transport Aircraft[a]	Helicopters	General Aviation	TOTAL	Commercial Transport Aircraft[a]	Helicopters	General Aviation
1969	13,505	514	534	12,457	$ 3,598	$ 2,939	$ 75	$ 584
1970	8,076	311	482	7,283	3,546	3,158	49	339
1971	8,158	223	469	7,466	2,984	2,594	69	321
1972	10,576	227	575	9,774	3,308	2,660	90	558
1973	14,709	294	770	13,645	4,665	3,718	121	826
1974	15,326	332	828	14,166	5,091	3,993	189	909
1975	15,251	315	864	14,072	5,086	3,779	274	1,033
1976	16,429	222	757	15,450	4,592	3,078	285	1,229
1977	17,913	155	848	16,910	4,451	2,649	251	1,551
1978	18,962	241	904	17,817	6,458	4,308	328	1,822
1979	18,460	376	1,029	17,055	10,644	8,030	403	2,211
1980	13,634	387	1,366	11,881	13,058	9,895	656	2,507
1981	10,916	387	1,072	9,457	13,223	9,706	597	2,920
1982	5,085	232	587	4,266	8,610	6,246	365	1,999
1983	3,356[r]	262	403[r]	2,691[a]	9,773[r]	8,000	303[r]	1,470[a]
1984	2,999	185	376	2,438	7,717	5,689	330	1,698
1985[p]	2,716	277	339	2,100	10,270	8,499	371	1,400
1986[e]	2,896[e]	315	481	NA	12,470[e]	10,614	456	NA

Source: Aerospace Industries Association.

a Due to the unavailability of general aviation forecast data, 1986 totals include 1985 general aviation figures for the purpose of estimating total shipments only.

(p) Preliminary.

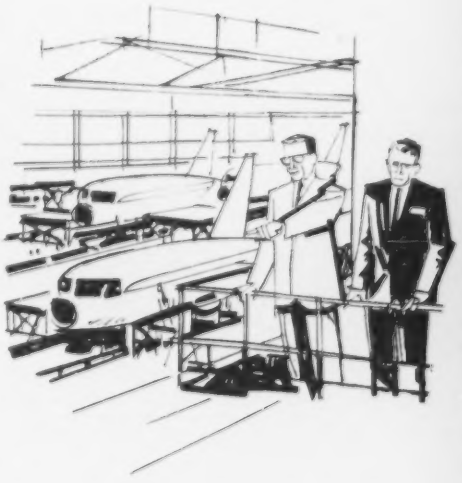
(e) Estimate.

(r) Revised.

Total shipments of civil aircraft declined in numbers but increased substantially in dollar value. This is explained by the fact that the areas of decline in numbers were in the lower-value general aviation and helicopter categories while shipments of high-value commercial transport aircraft increased significantly. Numerically, the industry delivered 2,716 aircraft, down 283 units from 1984 to a level that represents less than 15 percent of the total shipments in the peak year 1978. Total dollar value was 10.3 billion, up more than 33 percent over 1984. The $10.3 billion figure is the value of complete aircraft delivered during the year; it differs from the earlier listed civil aircraft sales volume of $13.6 billion in that the latter figure includes the value of spare engines and parts.

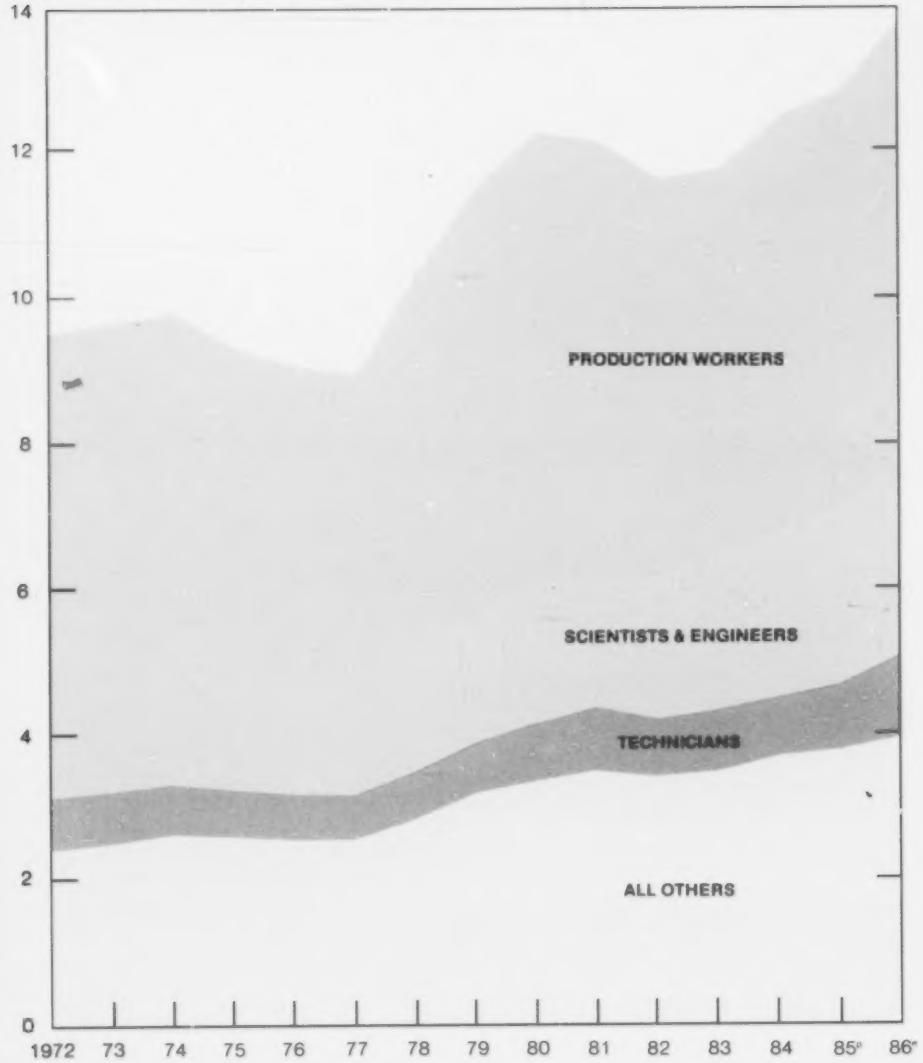
Commercial transports accounted for 83 percent of the total value of civil aircraft deliveries. The industry delivered 277 transports (up from 185 in 1984) worth $8.5 billion (up from $5.7 billion). Helicopter deliveries dipped by 27 units to 339, marking the fifth straight year of decline in numerical terms, but dollar value increased slightly to $371 million (up $41 million). General aviation shipments dropped by 338 units to 2,100 while value fell off from $1.7 billion in 1984 to $1.4 billion in 1985.

Projections for 1986 show total shipments of 2,896 aircraft worth $12.5 billion; however, the figures are only approximations because they assume 1986 general aviation shipments at the same level as 1985 due to unavailability of general aviation forecast data.



AEROSPACE EMPLOYMENT

(Hundreds of Thousands, as of December 1968-1986)

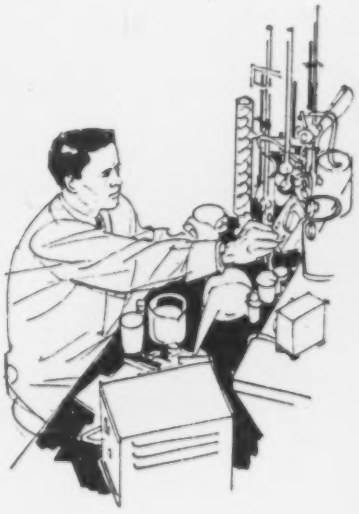


Source: Aerospace Industries Association, based on data from the U.S. Department of Labor, Bureau of Labor Statistics

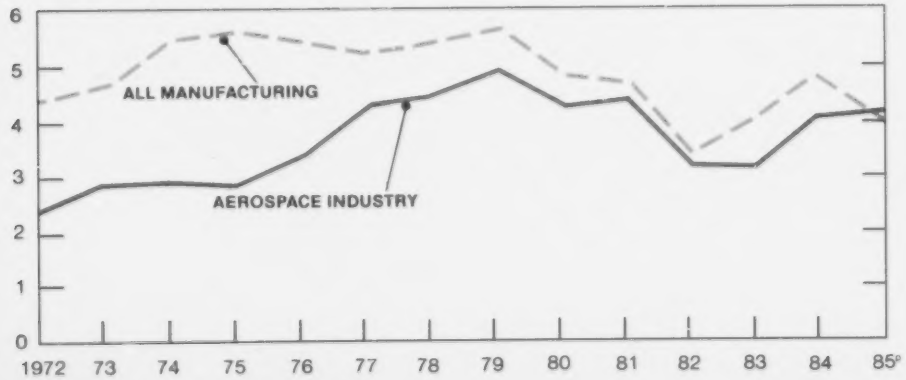
p Preliminary

e Estimate

At year-end 1986, the aerospace industry's labor force numbered 1,337,000, up from 1,250,000 at the end of the previous year; the 1985 level was the highest since 1969. The largest proportional increases were in scientists and engineers (up 11.7 percent to 248,000) and technicians (up 10.9 percent to 102,000). The number of production workers increased by 36,000 to 598,000 and there was a gain of 15,000, to 389,000, in the "all others" category. For 1986, AIA projects a modest two percent increase to a year-end total of 1,365,000.



NET PROFIT AFTER TAXES



Source: Aerospace Industries Association

p Preliminary

The aerospace industry recorded a profit after taxes of $4 billion in 1985, up from $3.6 billion in 1984. Measured as a percentage of sales, the profit rate was 4.2 percent, compared with 4.1 percent in the previous year, and an average of four percent for the five-year period 1980-84. The 1985 figure compares with an average profit of four percent for all U.S. manufacturing industries.

AIA

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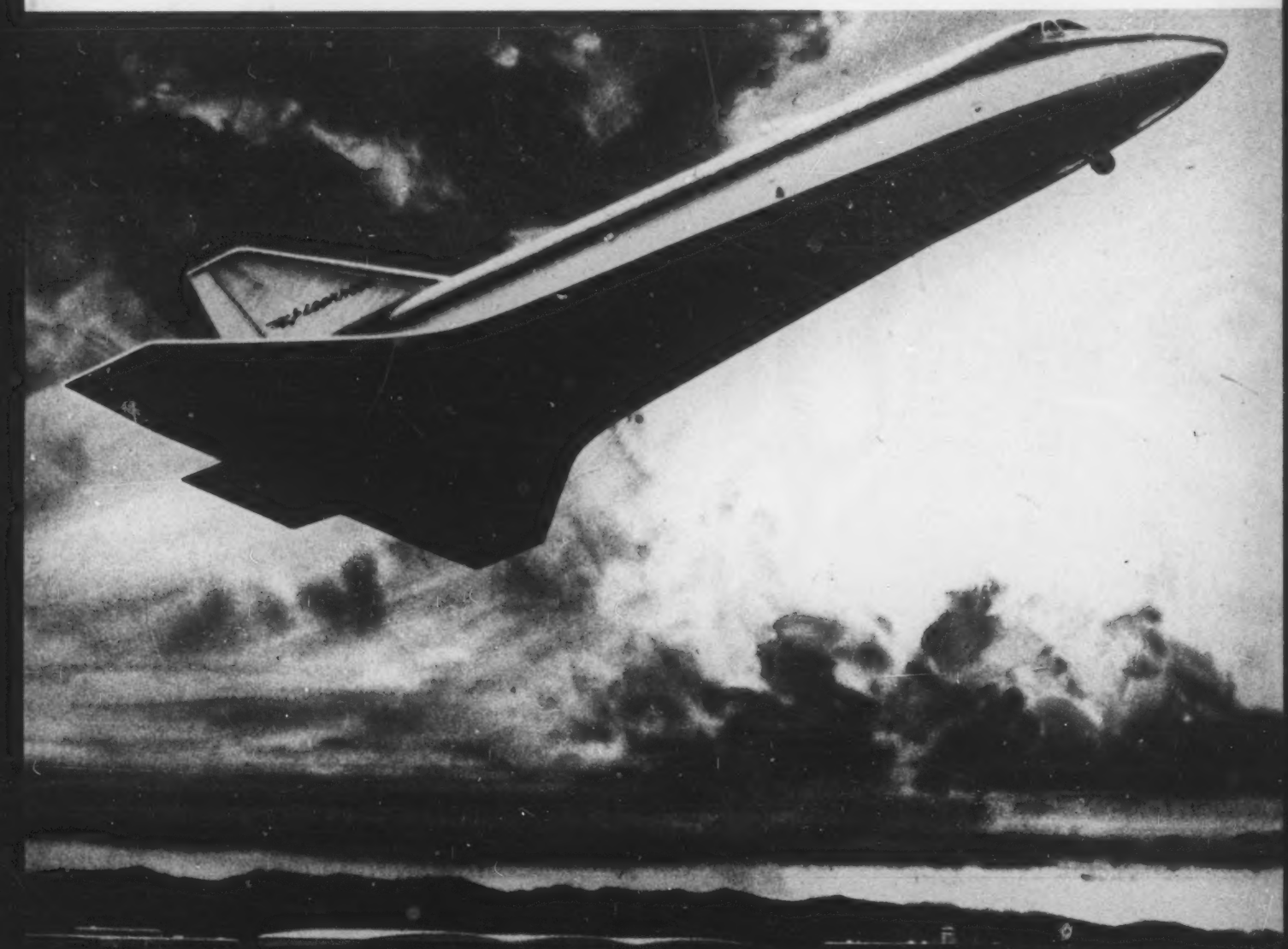

Notable views of notable people on aerospace matters...

aerospace perspectives

David Packard, *chairman of the President's Blue Ribbon Commission on Defense Management, summarizing the views of his commission in an article in The Washington Post:*

"It has become far harder to run the Pentagon. One reason is that Congress has gotten too involved in the details of defense management and has reduced the management authority and flexibility of the Secretary of Defense. As congressional leaders increasingly realize, the detailed annual budget review conducted by Congress creates a focus on year-to-year budgeting without much regard to defense missions, military strategy, operational issues or the costs of frequent changes in future defense budget targets.

"There are strong, perverse incentives for Congress, the military services and defense contractors to play games with the budget to accommodate pet projects. Programs are kept alive to satisfy parochial, not national, interests and are introduced without realistic notions of future costs. In this environment, coherent long range budget planning has become impossible.

"The acquisition of new weapons suffers from the lack of planning. The military services have often spent too little money and taken too little time to evaluate weapon systems and eliminate uncertainties about cost and performance before going into full-scale development or production. The key decisions that determine cost and performance are those made at the front end of the acquisition process. Poor judgment at that stage has cost the nation billions of dollars . . .

"Congressional efforts to legislate better management have merely added to red tape and created new layers of bureaucracy, which meddle in program management. The result is that when everyone is in charge, no one is in charge.

"Whatever the level of the defense budget, we need a new blueprint for defense management. We need new long-range planning procedures designed to produce a general agreement on the proper balance among funding, forces and strategy . . . We need better military advice to design forces within long-range ceilings . . . We need a stronger chairman of the Joint Chiefs of Staff to provide that military advice, to balance requirements for the readiness of our combat forces with the constant pressure for new weapons . . .

"We need a congressional review process that encourages stable programs and keeps its eye on key defense issues rather than line item details. We need a streamlined organization and process for buying weapons, headed by a full-time Under Secretary of Defense for Acquisition, equal in rank to the service secretaries . . . His watchword must be: "Fly, and know what it will cost, before you buy."

William H. Taft, IV, *Deputy Secretary of Defense, in an address to the National Security Industrial Association:*

"We fully support the Packard Commission's recommendations and are already carrying out the President's directive to implement them to the limits of our authority. However, the President and the Commission recognized that DoD is not the only player in defense management. Congress must also make changes, and not just by enacting legislation aimed at the Executive Branch but, what is much harder, by altering the way it conducts its own responsibilities for national security, if the Commission's recommendations are to be fully realized. Among the changes needed are reduction of line item decisionmaking by Congress; adoption of biennial budgets; and limitation of defense oversight to the committees properly charged with that responsibility. Most important of all, and related to these, are the changes needed to assure stability in defense policy, programs and budgets . . .

"The Packard Commission makes no more important point in its report than that there is an urgent need for stability in defense policy, programs and budgets. Such stability is the principal objective of its recommendations in the planning and budgeting area and is vital to the success of many of the reforms proposed in the acquisition area. Whether such stability is realized depends not only on the Executive Branch's undertaking the actions announced . . . but crucially on Congress . . . While the theory of biennial budgeting is loudly applauded on TV talk shows, the practice of bimonthly budgeting has been quietly and steadily gaining ground on Capitol Hill. The Packard Commission's objective of stability will not be realized unless this trend is reversed."

Caspar W. Weinberger, *Secretary of Defense, in the preface to the 1986 edition of Soviet Military Power, a Department of Defense publication:*

"With the initial deployment of mobile SS-25 intercontinental ballistic missiles to operational ICBM regiments in 1985, the Soviet Union confronted the world with further proof of its intensive drive for offensive military weapons capable of underwriting its political objectives against the West. Deployment of the SS-25 violates SALT II and the manner in which it has been based violates SALT I.

"The new, highly survivable, road-mobile, fifth generation SS-25s entered service as the deployment of the USSR's highly accurate, fourth generation, silo-based SS-18 Mod 4 ICBM program was reaching completion. Preparations were also under way for test flights of three future ICBMs being developed to build on the capabilities of the fourth and fifth generations.

"By the mid-1990s, nearly all of the USSR's currently deployed strategic nuclear attack forces—ICBMs, SLBMs and manned strategic bombers—will have been replaced by more advanced strategic nuclear weapons systems.

"Paralleling the offensive strategic developments of 1985, the Soviet Union pressed forward with advanced strategic defense systems . . . In 1985, the USSR continued to work on advanced strategic defense technology programs focused on the development of high-energy lasers, kinetic energy weapons, radio frequency weapons and particle beam weapons. These programs have already produced development ground-based radars capable of interfering with satellites. By the late 1980s, the USSR may well advance to the testing of lasers for targeting ballistic missiles in flight . . .

"Looking to the future, Moscow shows no indication of reducing the percentage of resources dedicated to the Soviet Armed Forces; the industrial capacity devoted to continued

force modernization; research and development, as well as the theft of Western technology, required for new generations of weapons systems; the commitment to improved readiness, mobility and sustainability to support Soviet forces; and the continued projection of power beyond Soviet borders. Indeed, by each of these measures, Soviet military power continues to grow."

General Robert T. Herres, *USAF, Commander-in-Chief of the U.S. Space Command, the USAF Space Command and the North American Aerospace Defense Command, writing in Signal magazine:*

"There has been widespread criticism about the Department of Defense's participation in the U.S. space program. And most of the criticism is expressed in pejorative terms such as "militarization of space" or "weaponization of space." The implication that runs through this type of criticism is that there is something sinister about the U.S. military's current activities in the space medium. However, the military's involvement in space has evolved from a national right of self-defense and from the historical use of the military as trailblazers of new frontiers . . .

"The space medium provides unique opportunities for commercial exploitation. However, it is unavoidable that the laws of physics offer those same unique opportunities to the military. The military has had a long and just legacy as pioneers of the United States' frontiers. And as long as its use of space is consistent with the defense interests of the United States and its allies, and in the interests of peace and stability, that use certainly is not sinister."

Admiral James D. Watkins, *Chief of Naval Operations, in an interview in International Combat Arms:*

"I believe, in spite of the good intentions, that the goal to eliminate the deficit by automatic formula is fraught with danger. We don't know all of the danger yet, but the caution flags are flying. We climbed the mountain to get this nation back on its feet in terms of Western world leadership—free world leadership. To come tumbling down the mountain before we reach the pinnacle would be a terrible setback we can't afford. We cannot rebuild the military to the extent we have and then suddenly take it all away. I believe it sends a questionable signal to all.

"Here we are pounding the Japanese and other allies in Europe to get up to three percent military spending in real growth terms and all of a sudden the U.S. goes instantly to negative real growth. What does it mean to our friends around the world? . . . Will irresponsible nations be deterred by our balanced budget? . . . I don't believe we want to slip back into the 'swamp' of the last decade, when we were little more than a paper tiger around the world, leaving the door open to the adventuristic Soviets and their surrogates."

Representative Jack Kemp, *New York, writing in the Wall Street Journal:*

"We must develop more realistic expectations about what any defense reform can achieve.

"We may have a bloated defense bureaucracy. We do not have a bloated defense budget. The gross inefficiency of the Soviet Union's centrally planned economy has not prevented a leadership willing to impose great sacrifice on Soviet citizens from accumulating enormous military might. Greater efficiency on our own part will not let us escape the consequences of that Soviet buildup.

"President Reagan's defense program has started us down the road toward regaining our strength. We must seize the opportunity for significant defense reform, but we must not allow reform to become a smokescreen for returning to the policy of weakness that threatened peace and freedom just a few short years ago."

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ON THE COVER. A Lockheed Advanced Aeronautics Company concept of a transatmospheric vehicle, operational offshoot of the National Aerospace Plane being developed by the Department of Defense and NASA *(see page 2).*

The purpose of AEROSPACE is to:

Foster understanding of the aerospace industry's role in insuring our national security through design, development and production of advanced weapon systems.

Foster understanding of the aerospace industry's responsibilities in the space exploration program.

Foster understanding of civil aviation as a prime factor in domestic and international travel and trade.

Foster understanding of the aerospace industry's capabilities to apply its techniques of systems analysis and management to solve local and national problems in social and economic fields.

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THE NATIONAL AEROSPACE PLANE PROGRAM

WHAT:

The National Aerospace Plane (NASP) research program is a joint Department of Defense/NASA program to develop and demonstrate the technologies for a revolutionary class of aerospace vehicles, powered by airbreathing engines, that would have the capability to take off from and land horizontally on standard runways, cruise in the atmosphere at hypersonic speeds, or fly into low Earth orbit.

WHY:

The NASP program is intended to revitalize American technological competitiveness in the commercial aerospace arena and to afford a significant increase in defense capability by effecting a technological giant leap, bypassing incremental advances in aeronautical technology and making a revolutionary jump into transatmospheric flight.

WHEN:

Although DoD and NASA have been conducting research in aeronautical hypersonics since the early 1950s, the current program dates to 1982 when the Defense Advanced Research Projects Agency (DARPA) initiated a new effort focused on supersonic combustion ramjet technology and, with NASA help in 1984-85, defined the airbreathing aerospace plane. The current phase of the work, beginning this year and continuing through 1988, involves accelerated development of key technologies, airframe design, development of a propulsion module and ground tests of the propulsion system up to Mach 8. A go or no-go decision on whether to proceed with an experimental aerospace plane — essential to testing beyond Mach 8, the limit of ground test capability — would be made late in 1988. If the decision is go and Congress provides the requisite funding, the X-plane would be ready for flight testing in 1992-95.

POTENTIAL:

Successful conclusion of the NASP program could lead to 21st century military or civil runway-to-orbit spaceplanes capable of rapid access to space, airplane-like flexibility and dramatically lower costs for delivering payloads to orbit. The same general technology could be applied to such non-orbiting vehicles as long range hypersonic military interceptors or civil passenger transports flying above 100,000 feet at speeds of Mach 6 (about 4,000 miles per hour) or more.

COST:

The Administration is requesting approximately $195 million in DoD and NASA funding for an accelerated technology development effort in Fiscal Year 1987. Estimated cost of the total multiyear program, including development of the X-plane, is $3.5 billion.

PARTICIPANTS:

The Air Force has been named executive agency for the program. NASA is charged with overall technology direction. Other DoD participants include DARPA, the Navy and the Strategic Defense Initiative Organization.

In April, 1986, the USAF awarded development contracts to seven aerospace manufacturing firms. Contracts for airframe design went to Boeing Aerospace Company, Lockheed Advanced Aeronautics Company, General Dynamics Corporation, McDonnell Douglas Corporation and Rockwell International Corporation. General Electric Company and Pratt & Whitney Division of United Technologies were awarded propulsion contracts. The airframe design competition will narrow the number of airframe contractors to two or three during the first year. Because the NASP design must integrate airframe and propulsion from the earliest stage, the propulsion contractors have associate agreements with each of the five airframe contractors. DARPA will manage the technology development phase.

THE REAL [illegible] PLANE

A Lockheed concept of an operational transatmospheric vehicle that could take off horizontally from conventional runways, accelerate to orbital velocity, operate in space as a payload delivery vehicle or as a maneuverable military spaceplane, and return to Earth for an airplane-like landing.

By JAMES J. HAGGERTY

In his February 1986 State of the Union message, President Reagan said, "We are going forward with research on a new Orient Express that could, by the end of the next decade, take off from Dulles Airport, accelerate up to 25 times the speed of sound, attaining low Earth orbit or flying to Tokyo within two hours."

The statement could have been clearer. The Presidential speechwriter might have leaned harder on the word *research* and added a phrase to the effect that the Orient Express and the advanced spaceline are possible future applications, not developmental projects in being. As it was, the statement was wide open to misinterpretation and many media reports presented garbled views.

Some took it to mean that the U.S. was ready to produce operational superplanes of the type described by the President. Not yet. Others got the impression that the hypersonic commercial transport and the orbital vehicle are one and the same. Not so. The potential orbital and

Development of transatmospheric technology could lead to a 21st century commercial transport carrying 300 to 500 passengers at 4,000 miles per hour or more (Lockheed concept pictured).

airliner applications are technological cousins that would be spawned from the same technology base but would emerge as substantially different vehicles.

One publication expressed the view that few commercial passengers would have the "right stuff" to board a "rocket plane" that would zip along at Mach 25, or 17,000 miles per hour. They need not worry about that for a while; it is well beyond foreseeable capability. The Mach 25 figure the President mentioned is the velocity necessary to attain low Earth orbit and it applies only to spacebound planes. A hypersonic atmospheric vehicle—whether a commercial transport or a military plane—would operate within a speed range defined by the Air Force as 4,000 to 8,000 miles per hour, roughly Mach 6 to 12. The history of commercial aircraft design, an endless battle of compromise in which performance is often traded off for greater productivity and producibility, suggests that a 21st century jetliner derived from transatmospheric technology would most likely operate at the lower end of the attainable speed range, around Mach 6. That would still be a tremendous advance in air transportation; it is three times the speed of the Concorde, the fastest jetliner, and more than six times as fast as the subsonic transports that handle the bulk of commercial air traffic today.

What the President was talking about was not immediate development of such aircraft, but a transatmospheric research and technology advancement effort that would pave the way for later development of a whole family of horizontal takeoff hy-

personic vehicles, some civil, some military, some flying in the upper atmosphere, some capable of accelerating directly to orbit.

Specifically, the President was proposing expansion and acceleration of an existing research program to include construction and flight test of an experimental vehicle to be known as the National Aerospace Plane (NASP). A joint Department of Defense/NASA effort, the NASP program involves development and flight demonstration of propulsion, materials, structures, flight control and other technologies essential to operational employment of transatmospheric vehicles. The NASP technology demonstrator will be a highly advanced X-plane, a new member of the illustrious family of special research aircraft that includes the X-1, which in 1947 proved the feasibility of supersonic flight, and the X-15, which in the 1960s became the first man-carrying hypersonic vehicle and ultimately attained a speed of Mach 6.7, about 4,500 miles per hour.

NASP is a tremendously important research program that could significantly strengthen the U.S. defense capability and simultaneously effect a position of clear-cut product superiority in the international marketplace of the 21st century. The Office of Science and Technology Policy's Aeronautical Policy Review Committee, which recommended accelerated research in the transatmospheric regime as one of the National Aeronautical R&D goals propounded last year, had this to say:

"The capability to routinely cruise

and maneuver into and out of the atmosphere, to gain rapid responsiveness for low Earth orbit missions, or to attain very rapid transport services between Earth destinations from conventional runways, must be viewed as aerospace options with global importance for the future. The importance of these capabilities to the U.S. must be underscored, since all these possibilities are also open to foreign military or civil initiatives in either areonautics or space...

"Increased understanding of the transatmospheric environment and its relationship to maneuvering vehicle requirements must be gained within the near term. The knowledge will be highly significant to the selection of high-payoff developments in propulsion, fuels, materials, system concepts and other areas...The question is not whether these advances will be made—only *when* they will be achieved and by whom. The benefits are too valuable to remain untapped by competitors and adversaries for long."

It's a safe bet that the Soviet Union is exploring transatmospheric technology and there have been reports of a Shuttle-like spaceplane in development. The United Kingdom is conducting a research program called HOTOL, for horizontal takeoff and landing launch vehicle, a hypersonic craft intended primarily for delivery of satellites to geosynchronous orbit. Although a later manned system is contemplated, HOTOL will initially be unmanned and it is not targeted for first flight until 1997. So far HOTOL is a lightly-funded study program and the UK is trying to find European partners to share development costs. France, meanwhile, is planning development of Hermes, a mini-Orbiter that would be boosted by an advanced Ariane launch vehicle. But Hermes, which is also planned for late 1990s debut, is competitive only in the sense that its development involves some hypersonic technology; the project will not help France develop the horizontal takeoff and airbreathing engine technologies essential to routine transatmospheric flight.

So, while there is no doubt that these and other nations are eyeing the potential benefits of a transatmospheric capability, the U.S. would appear to be best positioned to take advantage of the opportunity. The U.S. has a solid lead in the key technologies. The Space Shuttle represents more than 15 years of hypersonic research, development and experience and it is the world's only hypersonic vehicle capable of flight to orbit and return to an airplane-like Earth landing. In addition, NASA, the Department of Defense and U.S. industry have for years been researching advancements in airbreathing propulsion, structures, materials, flight controls and aerodynamics for hypersonic flight. All these technologies have reached a level of maturity sufficient to justify a flight demonstration program. Says Ben R. Rich, president of Lockheed Advanced Aeronautics Company: "Four of the five key technologies necessary to develop this type of aircraft already exist. The one technology that remains to be developed is the propulsion system. But even in this area we are on the verge of success."

Lockheed's Ben Rich:

"We stand at the threshold of an opportunity to create an exciting new airplane — an opportunity to use the technology honed over several decades... to develop an aircraft for commercial use that can fly at speeds of Mach 6 and possibly higher... It makes sense. It is feasible and clearly there is a need for it."

The primary propulsion system for NASP will be the supersonic combustion ramjet engine, or "scramjet," which does not have the jet engine's compressor but uses the velocity of the vehicle to compress air as it is "rammed" into the intake. Thus compressed, the air is mixed with liquid hydrogen, which has the most energy per pound of any fuel, and burned to generate very high thrust. The scramjet has already demonstrated — in ground facilities — sufficient thrust to propel a vehicle at Mach 7; that's close to the limit of ground test capability and that's why a flight program is essential for further development.

Because ram compression does not work well at subsonic or low supersonic speed, NASP will need an auxiliary propulsion system to accelerate it to a velocity high enough for the scramjet to take over. And since the scramjet gulps great quantities of air, it becomes ineffective at near-orbital altitudes where the air is too thin; so it will also need a "kick engine," a rocket system for the final thrust to orbital velocity. The transatmospheric vehicle will not have three separate types of engines, rather one multiple-cycle propulsion system.

The experimental NASP, assuming Congressional assent, would commence test flights in the early to mid-1990s. The craft will probably be something about the size of a Shuttle Orbiter with a crew of two and only enough payload for acquiring the essential instrument data. The NASP, said NASA Associate Administrator for Aeronautics and Space Technology Raymond Colladay, will be "capable of effective operation over the entire Mach number range to reach orbit," which is zero to Mach 25. Colladay added that demonstration of scramjet technology "certainly isn't a piece of cake," but he expressed confidence that the remaining technological problems can be solved.

If NASP successfully demonstrates the requisite technologies, the first operational application could be flight-ready by shortly after the turn of the century. It would no doubt be an Earth-to-orbit vehicle, because the requirements for such versatile space systems, in both military and civil operations, are more urgent than for atmospheric applications. In civil space, there will be a need around 2000 for an advanced Shuttle and transatmospheric technology offers a very big advantage: a dramatic reduction in payload delivery costs, variously estimated from one-tenth to one-hundredth current costs. This is due principally to the elimination of

the elaborate facilities and lengthy countdown operations necessary in today's vertical launches.

For military operations, the advanced aerospace vehicle fulfills a wide range of needs, in particular the need for rapid access to space that an airplane-like horizontal takeoff craft would afford. In a recent speech, General Lawrence A. Skantze, Commander, Air Force Systems Command, summed up the potential utility of an operational aerospace plane:

"We're talking about the speed of response of an ICBM and the flexibility and recallability of a bomber, packaged together in a plane that can scramble, get into orbit and *change* orbit so the Soviets can't get a reading accurate enough to shoot at it. If offers strategic force survivability — a fleet could sit alert like B-52s. The advanced aerospace vehicle has potential for reconnaissance, rescue and other missions. But, of paramount importance, it could mean low-cost, reliable access to space, precisely what's needed to open up the space frontier to routine operations."

In Capitol Hill testimony, DARPA officials advanced some other possible applications of aerospace plane technology to atmospheric flight. It could, they said, be employed in a Mach 12 (8,000 miles per hour), highly survivable reconnaissance airplane flying at 200,000 feet; as a 21st century successor to the Advanced Technology Bomber; as a manned interceptor; or as an unmanned, long-range air defense missile.

What about the "Orient Express" or commercial hypersonic transport? Is it really feasible or just a pleasant fantasy? Members of the It Will Never Happen Society, the perennial critics of all technological advances, point out such seemingly insurmountable obstacles as the sonic boom that sharply curbed Concorde's use, the enormous development costs, and the very limited market for a Concorde-like super-premium-fare airplane of restricted utility.

Proponents dismiss the sonic boom consideration. The severity of sonic boom perception on the ground is a function of several factors, including altitude and air density. The hypersonic transport would be flying so high that the extremely thin air would lessen the boom, and its sound would be further dissipated by the distance it must travel to the ground — more than 20 miles. The boom, says an Air Force fact sheet, "will be more on the order of a 'sonic tap' ". If so, the commercial vehicle could fly over land areas at supersonic/hypersonic speeds, a big advantage denied the Concorde.

As for development costs, the R&D costs will be borne by the government to meet urgent military and civil space needs. The government-sponsored NASP program, followed by development of operational vehicles of the advanced Shuttle/military orbiter/military atmospheric plane variety, will create a broad technology base on which developers of a commercial airplane may draw. Government pathfinding work will not eliminate commercial development costs, but it could make them manageable.

As for repeating the Concorde experience, no company, consortium or nation is going to invest in a commercial airliner that would have very restricted utility and would demand extraordinary passenger fare levels. Proponents believe that scramjet technology and advances in other technologies can curb operating costs while significantly elevating transport speed, and that airlines may be able to offer hypersonic travel for something not far beyond today's subsonic fares. And they see the superspeed transport not as a limited use vehicle confined to a few over-ocean routes, but as the dominant craft in all long haul transportation, over land or over water.

That's because significant changes in world commerce and transportation are expected between now and, say, 2010, realistically the earliest date for possible commercial hypersonic travel. Studies point out that population will continue to grow and that more than 75 percent of the growth will be in the developing nations of the Pacific Rim, South America, Asia and Africa. Increasing trade with these nations will involve transportation at very long stage lengths, and that in turn will demand greater speeds.

Lockheed's Ben Rich amplifies that point, using the Pacific Rim example:

"This new vehicle has particular economic application to the Pacific Rim region (which) has the fastest growing population and economy in the world . . . A major constraint on air travel across the Pacific or across Asia to Europe is the time required. Travel is costly, in terms of time, comfort and economics . . . Conventional air travel between the U.S. and Europe takes seven hours, four hours on the supersonic Concorde. By comparison, conventional air travel from the United States to Singapore requires 22 hours . . . The development of the aerospace plane would cut that travel time to a fraction and would have major implications for U.S. trade and alliances in the Pacific because it would offer the potential for creating long-term bonds between these countries . . .

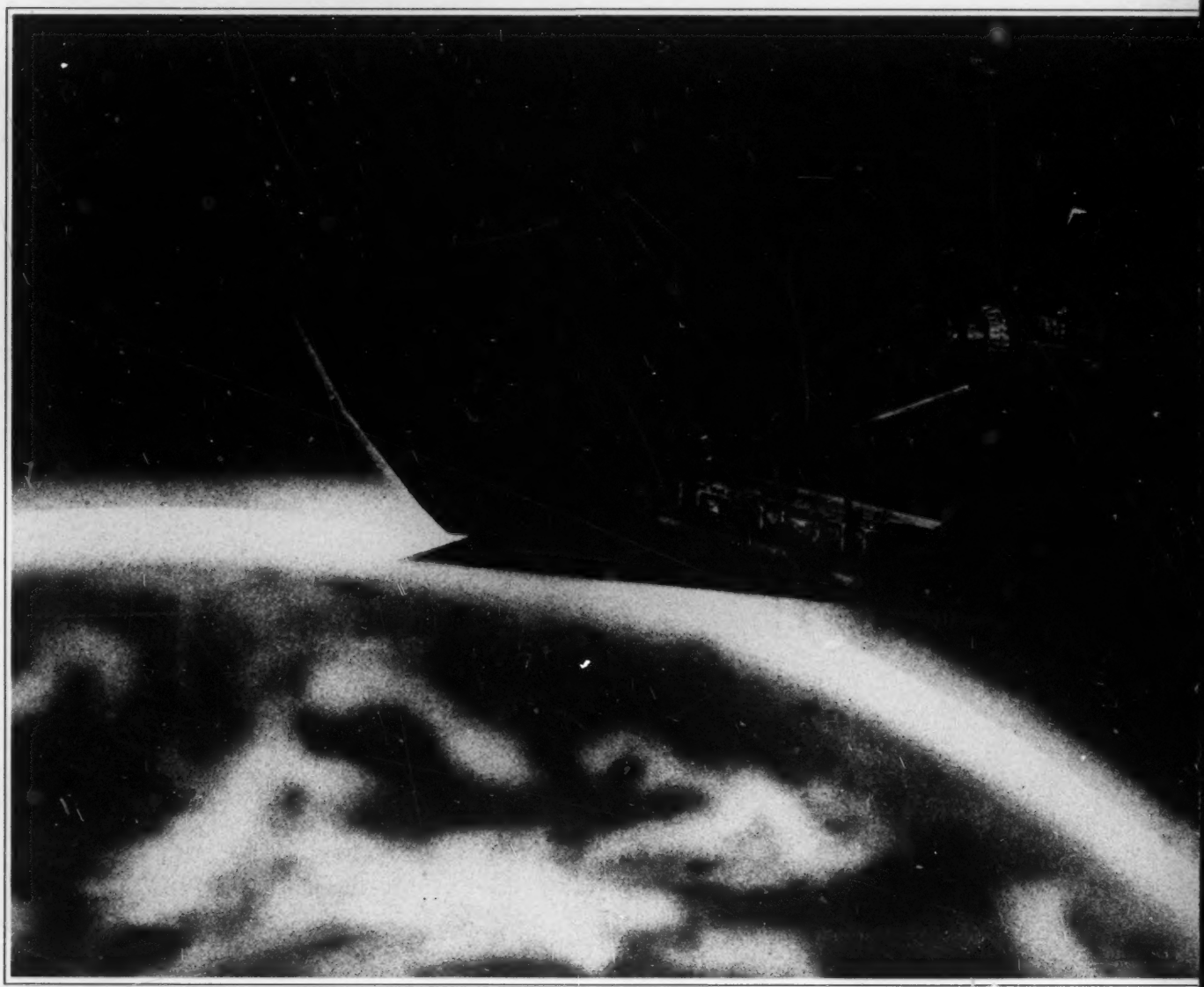
"We stand at the threshold of an opportunity to create an exciting new airplane — an opportunity to use the technology honed over several decades . . . to develop an aircraft for commercial use that can fly at speeds of Mach 6 and possibly higher . . . It makes sense. It is feasible and clearly there is a need for it."

General Lawrence A. Skantze:

"We're talking about the speed of response of an ICBM and the flexibility and recallability of a bomber, packaged together in a plane that can scramble, get into orbit and *change* orbit so the Soviets can't get a reading accurate enough to shoot at it."

THE REALM OF THE POSSIBLE

The USAF's Forecast II looks at long term technological promise rather than short term need



A high payoff technology advancement identified in Project Forecast II is the military aerospace plane, which would provide low-cost transportation to space and greatly expanded maneuverability in orbit.

It is theoretically possible to combine protons and antiprotons to generate enormous bursts of energy, 100 million times more than can be effected by chemical reactions. That kind of energy offers a potential solution for the biggest problem in military or civil space exploration: the heavy fuel expenditure — hence high cost — of putting payloads into orbit. With the hypothetical antiproton reaction, it would be possible to send a spacecraft the size of a 747 to the moon with 50 tons of payload — and the "fuel" would weigh less than a gram.

Sounds "way out" — but it's the subject of a serious Air Force investigation. Not that the USAF expects to be operating antiproton spaceships any time in the near future. It's just something that is worth a long look, an emerging technology that might have tremendous 21st century impact on Air Force operations — or might fall by the wayside. It cropped up in the course of Project Forecast II, an Air Force Systems Command (AFSC) exercise in surveying technologies on the horizon and deciding if and how such technologies could enhance warfighting systems. The recently completed Forecast II was designed as a reach into "the realm of the possible," a departure from the conventional way of launching new weapon system developments on the basis of "what's needed soon."

"Project Forecast II was a critical avenue to push the state of the art in technology to guarantee our edge over our adversaries," said AFSC Commander General Lawrence A. Skantze. "It's different from daily military R&D work. For the near term, Systems Command thinks in terms of satisfying the needs of the commands. The object of Project Forecast II was to think longer term, to discern the art of the possible and to push the state of the art, not to react to immediate technology requirements . . .

"Stealth (the Advanced Technology Bomber) showed us what can happen when researchers think more about technological possibility than reacting to a specific operational need. Traditionally, to penetrate enemy defenses, we'd opt for better electronic combat, more firepower or faster aircraft with more maneuverability. Stealth broke the mold — a means to make things electronically invisible was a solution we didn't anticipate. Technology pushed a solution to meet an Air Force need."

As the designation indicates, Forecast II is the second Air Force exercise of its type, third if you include a World War II technology survey conducted when the Air Force was still a part of the Army. Dr. Theodore von Karman headed a study group that probed far-out technology in response to an instruction from General of the Air Force H. H. "Hap" Arnold: "Divorce yourselves from the present in order to investigate all the possibilities and desirabilities of future weapons development." Von Karman and his colleagues did exactly that and produced a report — "Toward New Horizons" — that drew a technological roadmap for the postwar direction of the Air Force.

The original Project Forecast was conducted in 1963–64 under the leadership of General Bernard A. Schriever, then commander of AFSC. From the technologies identified in Forecast I as potentially applicable to major advances in USAF equipment, there emerged such develop-

ments as large cargo aircraft like the C-5; the Advanced Manned Strategic Aircraft, which led to the B-1B; use of lightweight composite materials in operational aircraft; high thrust-to-weight turbofan engines; and reusable space vehicle technology that was ultimately incorporated in the Space Shuttle.

For Project Forecast II, Systems Command brought together the best talent in USAF headquarters, commands and laboratories and backed them with a blue ribbon advisory group composed of retired Air Force generals, top executives of defense industry, deans and presidents of leading colleges and universities, current and past members of the Defense Science Board and the Air Force Scientific Advisory Board.

The brainstorming sessions began on August 1, 1985 and continued for six months. They uncovered initially about 2,000 different ideas, described by Skantze as "some great, some good, some not so exciting." The ideas were evaluated by three separate groups: a technology panel, a mission panel and a cost/threat analysis panel. These panels sifted out the most promising, highest payoff emerging technologies, narrowing the field to some 70 ideas for new systems and technology advancements. AFSC will explore all 70 but will put special effort into investigation of about 20 of them that are not only especially promising of military utility but also offer important civilian spinoff potential.

"The findings of Forecast II point to a revolution in several technology areas," said Skantze. "The biggies are information systems, including expert systems, materials, non-linear optics, life sciences, hypersonics and propulsion. The work we'll be doing in these areas ranges from low risk to high risk. We've gathered the highest leverage technologies that had no show stoppers. Our labs may find out later that some ideas won't work or are too expensive. We expect this Weapon system R&D always involves risk. Without risks there are no breakthroughs. The Air Force is prepared now to get to work on the next century's technology, to uncover what the world has never seen."

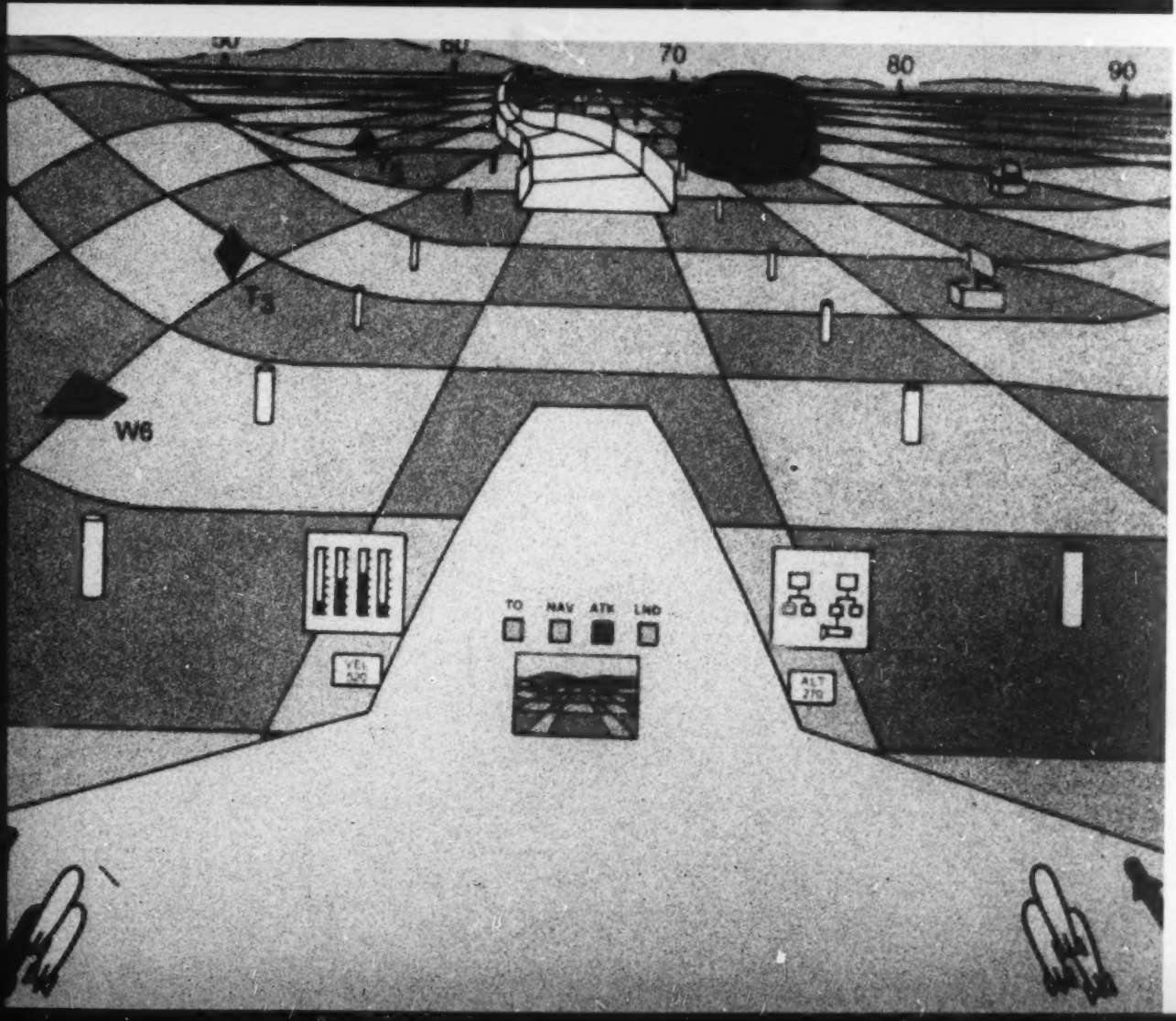
Among the initiatives to be explored, Skantze said, "some are small but with tremendous ramifications. An example is smart, built-in test devices for electronics; they could eliminate false alarms in electronic equipment."

And there are a number of "biggies," one of them the antiproton energy system which, says AFSC, could revolutionize space travel in the next century. "The theory identifies two types of hydrogen particles, one positively charged as a proton, the other negatively charged as an antiproton. Joined together, the two annihilate each other totally, producing pure energy which could provide rocket thrust. For a vehicle already in space, a small portion of this propellant could be used to create continuous acceleration, cutting travel time to the moon or planets significantly." As for civil potential, AFSC suggests that the tremendous energy of proton/antiproton reaction might ultimately be the answer to future non-fossil energy resources.

Another biggie identified by Forecast II is the program that has now become the National Aerospace Plane (see page 2). This program envisions development of technology for a family of vehicles capable of taking off horizontally from conventional runways and accelerating directly to orbit or, alternatively, flying in the upper atmosphere at speeds from 4,000 to 8,000 miles per hour. The major advantage, to both military and civil space operations, is low cost access to orbit, about one-tenth the cost of the Space Shuttle. Air Force uses of operational aerospace planes include payload delivery, retrieval and repair; a maneuverable-in-orbit space rescue vehicle; a superspeed 21st century

The "Swarm" concept envisions large numbers of small, low-cost satellites performing the jobs now handled by big, expensive and highly vulnerable spacecraft.

In Systems Command's Super Cockpit concept, a combat pilot would get a computerized, helmet-mounted visual display of "real world" conditions, such as enemy aircraft (yellow box), friendlies (white airplanes), his armament (foreground) and the defense threat, such as a missile base (red).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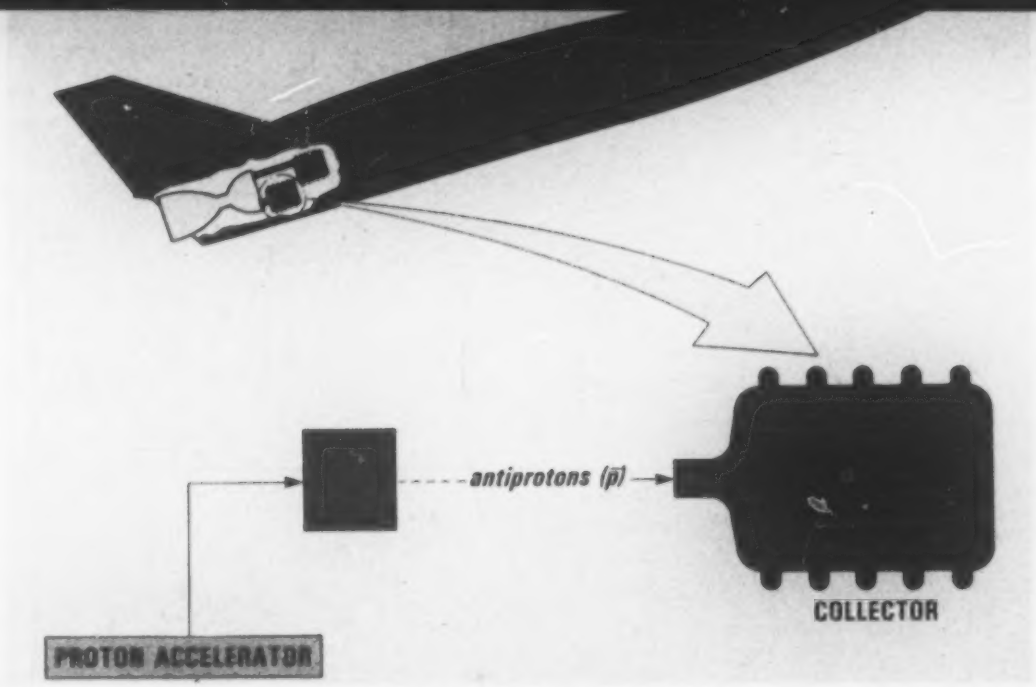


A far-out possibility: a revolutionary antimatter propulsion system generating enormous energy for rapid travel to the moon or planets.

successor to the Advanced Technology Bomber; a surveillance aircraft flying at 8,000 miles per hour at more than 200,000 feet; a long range interceptor; or a cruise missile carrier. The civil spinoff: a hypersonic commercial transport, operating above 100,000 feet at about Mach 6, or 4,000 miles per hour.

Forecast II also produced the "Swarm" concept of unmanned space operations, wherein a large number of small, relatively inexpensive satellites with high capability in the aggregate would replace the small number of highly capable, ultra reliable but very vulnerable satellites now in service. Present satellites are complex and usually specialized, designed for a single job; the allowable launch weight limits size and functions, the allowable size limits sensor performance, and the need for reliability demands redundant systems, increasing cost. Why not, Forecast II brainstormers asked, use an array of individually less capable but less costly spacecraft working together in synchronized operation in such tasks as communications, navigation and radar monitoring?

"For a space-based radar," says AFSC, "many small spacecraft the size of refrigerators could do the same job as a single massive spacecraft the size of three tennis courts." There might be a cost advantage but the principal gains would be improved reliability, greater survivability and growth capability — by simply adding more spacecraft. The Swarm concept, AFSC thinks, could have civil application in such areas as low-cost communications, hazardous weather tracking or air traffic control.

A Forecast II idea already in early research status is the Super Cockpit. The amount of information needed and processed by a pilot of a military combat airplane is staggering in volume and complexity and approaching the limit of aircrew absorption in a modern electronic warfare environment where decision time is sharply compressed.

Today, information is presented to the pilot — or crew — on dials and cockpit displays; humans must integrate all this information and mentally transform it into real world conditions. A better way to present the information is the "see, hear the world as it is" approach. Anticipated advances in information sensing and processing will allow visual displays in the pilot's helmet visor that would give him a computer image of the real world outside his aircraft as well as status reports on the equipment in his airplane. He would see, for example, enemy aircraft not as radar blips but as miniature airplanes in red, friendly aircraft in white and a threat situation — such as an enemy missile base — indicated by a large red square. This, AFSC feels, would enable easier information retention by pilots, even under the harshest combat conditions. Much of the technology would be applicable to use in private and commercial airplane cockpits or to air traffic control centers, offering potential for reduced controller fatigue and lessened chance of misunderstanding informational displays.

One more Forecast II technology is robotics/telepresence — the use of robots remotely directed by humans — to perform maintenance and repairs in environments where human life would be at risk. While the human brain cannot be duplicated as a processor, the robot can perform a variety of functions if, by telepresence, a remotely-located operator can perceive what the robot sees and feels. Examples of military applications include construction or repair in a combat environment, explosive ordnance disposal, or moon base operations.

AFSC plans to pursue these and other technologies actively, to the extent that funds allow. The Air Force is allocating a percentage of its science and technology base funding to Forecast-inspired investigations and is redirecting other efforts "to put the primary focus on some of these thrusts that we think have the best payoff." Additionally, said General Skantze, "We'd like to generate enough interest to get industry to complement Air Force investments with their own money. Independent research and development programs that explore candidate technologies identified through Forecast II could lead to competitive advantages downstream."

"Ultimately," he added, "it's intellectual — rather than financial — resources that will make this project work. Inputs must be creative and unfettered. We have to think beyond being reactive to the Soviet threat. We should make them react to our threat, render their efforts obsolete and negate the effectiveness of their countermeasures."

HIGH TECH FOR THE DISABLED

By ELLEN I. KELLY

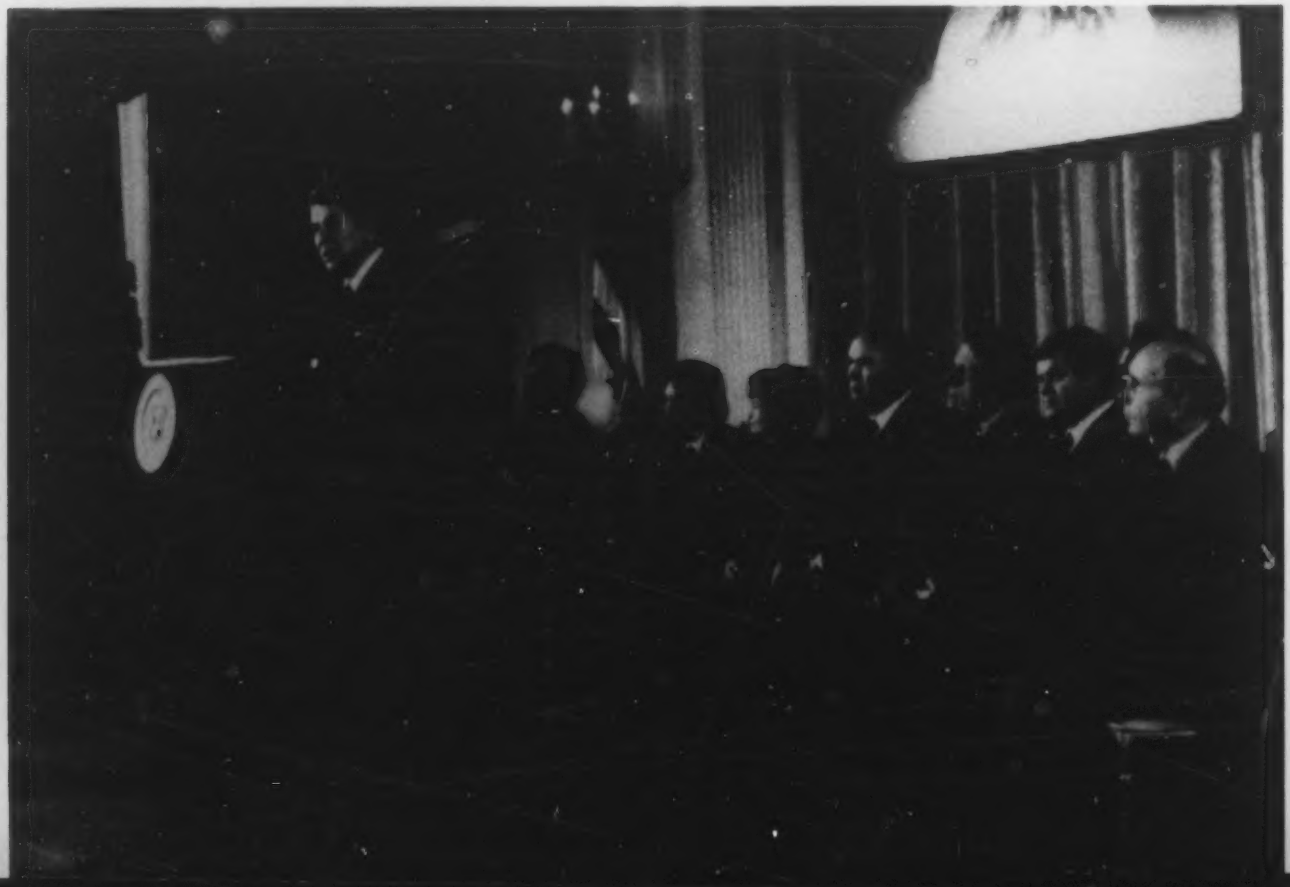
A 24-year-old woman, paralyzed in a car accident, is able to use her only movement—the blinking of her eyes—to communicate. A specially developed infrared sensor attached to her eyeglass frames allows her to spell out words on a video screen by opening and closing her eyes.

Two teenaged brothers suffering from muscular dystrophy mastered computer drafting skills on a special personal computer operated by a joystick. Both are now employed using these skills.

A quadriplegic computer programmer uses a prototype integrated work station that responds to his voice commands. Special software enables him to answer the telephone and a robotic control system is now being programmed to lift his manuals and papers and to handle his floppy disks.

Such applications of technology have dramatically improved the lives of these and other disabled people, but the fact is that the technologies themselves are neither dramatic nor revolutionary. They have been borrowed and adapted from the high tech world created by American industries that have put men on the moon, devel-

At a December 3, 1985 White House ceremony, President Reagan honored former HHS Secretary Margaret Heckler and members of the Executive Coalition for the National Initiative on Technology and the Disabled. Seated behind Reagan, from left, are Susan Yim, a quadriplegic who uses a computer to communicate; Jackie Julio, a law student who uses a motorized wheelchair with a device for typing; Heckler, Robert Kirk, president and chief executive officer, LTV Aerospace and Defense; Malcolm Stamper, vice chairman, The Boeing Company; Jack Pierce, treasurer, Boeing Company; (barely visible) Charles Locke, chairman and chief executive officer, Morton Thiokol; and Harry Gray, chairman and chief executive officer, United Technologies Corporation.



oped sophisticated modes of communication, and evolved scores of other technological developments that advance and improve our health, our economic well-being and the nation's security.

But the challenge this time is different. It involves less emphasis on new technological discoveries; rather, it primarily involves discovery of mechanisms for applying the knowledge of the technical world to the special problems facing the disabled.

Meeting that challenge is the goal of a national program, the Private Sector Initiative for Technology Enlisted to Conquer Handicaps (PSI-TECH), launched in January 1985 after President Reagan proclaimed 1983–1992 as the "Decade of the Disabled." Basically, the program works through two elements: TECH-NET, a national, readily accessible communications/information network serving the entire disabled community; and TECH Teams, a nationwide system of locally based teams of technical and other experts formed to apply technological developments to problems facing people with disabilities.

Initial endorsement for PSI-TECH came from the Department of Health and Human Services under former Secretary Margaret Heckler, the National Aeronautics and Space Administration and the Department of Defense. Jack Pierce, treasurer of The Boeing Company, was a leader in the effort. A National Advisory Board on Technology and the Disabled was appointed by Heckler to provide advice, consultation and assistance for the program.

As a private sector initiative, however, PSI-TECH could not receive government funding. Consequently, the originators called on the aerospace industry—one of the nation's leading high tech industries—to raise the seed money for the program. In July 1985, industry leaders formed the Executive Coalition for the National Initiative on Technology and the Disabled. Chaired by Robert L. Kirk, President and Chief Executive Officer of LTV Aerospace and Defense Corporation, the Coalition obtained pledges of $1.2 million from members of the Aerospace Industries Association (AIA) to support PSI-TECH. Kirk, who also serves as Chairman of AIA's Board of Governors, was joined in the Coalition by Robert Anderson, Chairman of Rockwell International; Roy Anderson, Chairman of Lockheed; Jack Heckel, Chairman of Aerojet General; Charles Locke, Chairman of Morton Thiokol; Thomas Pownall, Chairman of Martin Marietta; Roger Smith, Chairman of General Motors; Malcolm Stamper, Vice Chairman of the Boeing Company; T. J. Murrin, President of the Energy and Advanced Technology Group of Westinghouse; and D. Brainerd Holmes, President of the Raytheon Company.

President Reagan honored Heckler and members of the coalition at a Decem-

Prior to the December 3 White House ceremony, Heckler awarded LTV's Kirk the HHS Distinguished Public Service Award and other coalition members the HHS Distinguished Volunteer Service Award. From left are Morton Thiokol's Locke, Kirk, Heckler, United Technologies' Gray, and Boeing's Stamper.

Tom Cusworth, a systems designer working for Concepts for Independent Living to implement TECH-NET nationwide, operates the Seattle-based prototype system. Containing more than 5,000 entries, the TECH-NET provides aid and information to the disabled.

A Boeing Company quadriplegic computer programmer uses voice commands to instruct a robot arm. His "VOICE Workstation" was developed by Boeing scientists and engineers and eventually will be adapted for other disabled Boeing workers.

ber 3, 1985 White House ceremony. Calling PSI-TECH "an exciting partnership between the government and private sector," Reagan said, "If we could give astronauts jetpacks, couldn't we give the disabled a better wheelchair? If we could enable a spacecraft Orbiter to talk to Houston Control, couldn't we help those with speech impairments?"

Kirk, who received the Health and Human Services Department's Distinguished Public Service Award in December 1985 for his efforts, has echoed the President, saying that the uniqueness of the aerospace industry enables it to contribute much more than funds to PSI-TECH. "Our industry has been accustomed to challenges since the dawn of flight. We believe that our track record in solving difficult problems is well established . . . Applying scientific and technological discoveries to enhance the lives of disabled people is an exciting prospect—as exciting to us as our exploration of the universe," he said.

In addition to pledging funds, many AIA companies have completed surveys of existing efforts to assist disabled people in their work forces and in their communities. The surveys have been turned over to Concepts for Independent Living, the Seattle-based nonprofit organization chosen to administer PSI-TECH. Boeing's Pierce serves as Chairman of the organization, which has examined the independent living problems of the disabled since its formation in 1978.

Fundraising efforts for PSI-TECH, according to Concepts Executive Director Carl Krafft, are now being extended to other high tech companies and to other segments of American industry. He estimates the cost of the PSI-TECH development plan to be $5 million.

Concept's staff of 14, including four in a national office in Washington, D. C., is working to implement all phases of the program. To date, much of the effort has been devoted to a prototype TECH-NET system in Washington state. Housed in an independent living center in Seattle called the Resource Center for the Handicapped (RCH), the TECH-NET became operational in August 1985. Installed on a high speed computer, the system has four available data bases, including: a Service Referral, consisting of 4,000 entries; an equipment exchange, made up of 350 constantly changing entries; a publication referral, including 1,200 entries; and a talent registry, comprised of names of volunteers. Additional data bases under development include TECH Team information, civil/legal rights, peer interest groups, local employment opportunities, and an open bulletin board for sharing information.

According to Tom Cusworth, a systems designer for Concepts, traffic on the TECH-NET system averages between 18 and 25 calls per day. Cusworth, a quadriplegic himself who operated the TECH-NET for RCH before joining Concepts, said 80 percent of the callers receive some type of direct help or referral. "The best examples of the success of the system so far are the equipment exchanges," Cusworth said. One example is a young boy suffering from cerebral palsy who received an electric lift to raise his wheelchair into his van. "His father is in jail until 1990, his mother abandoned him, and his guardian had no way to pay for a lift," Cusworth said.

There are plans to establish TECH-NET systems in Kansas, Massachusetts, Pennsylvania and Texas by fall 1986. Concepts is preparing replication kits to include the initial level software programs; training, operation and administrative manuals; and generic promotional materials such as brochures, public service announcements and newsletters. Negotiations to procure the computing equipment for the 50 state installations, also to be included in the kit, are under way. A feasibility demonstration linking these four states with the Washington prototype will

VME

This device, developed by VME volunteers, allows a quadriplegic to use his hand for grasping objects.

Volunteers for Medical Engineering founder John Staehlin worked with other volunteers to develop this modified mobile standing frame for those who cannot walk. Its bicycle wheel adaptation and new braking system make it a more efficient and affordable unit.

be conducted late in 1986, and the goal is to have systems in all 50 states operational by the end of 1988.

"We are approaching each state through the governor's office," Krafft said. "Our plan is to select an organization or individual in each state and provide them with the start-up material. From there, the selected group will be responsible for operating and financially maintaining the system."

Research into establishing TECH Teams has consisted of identifying on a national scale similar endeavors and products under development. In researching what is available, Krafft said, "We're overpowered with what we're finding. Our objective is to develop a program by which all the information relative to the many isolated cases we're discovering gets cranked into TECH-NET so it will become available to anyone interested."

A matrix currently containing 163 organizations and efforts nationwide that serve the disabled community is being maintained by Concepts.

Examples abound of such teams already in existence in the aerospace industry alone. In recent Congressional testimony, coalition chairman Kirk emphasized the importance of tying these independent efforts into TECH-NET, saying, "Today there are approximately 35,000,000 disabled Americans. Although many aerospace companies have employees engaged in activities intended to benefit disabled persons, the results—while dramatically good for a few people—are still not widespread."

A prime example is Baltimore-based Volunteers for Medical Engineering (VME). Most of its 200 volunteer engineers, scientists and technicians are employees of Westinghouse Electric Corporation. The company donates money ($65,000 in 1985), tools, equipment and in some cases material for volunteers to use in solving their clients' problems. Krafft said Concepts and VME have been in close contact to work out a system to mutually assist each other. "VME fits exactly with what we want to do," he said.

John Staehlin, an advisory radar antenna engineer for Westinghouse, founded VME in 1981 to "donate aerospace and defense technology to the needs of the disabled."

Staehlin, who says he "likes to invent things," first thought of the idea in the 1960s. "I just got sidetracked until a few years ago when I finally decided to force the issue," he said. Teaming with his family and Dr. Arthur Siebens, director of rehabilitation programs at the Johns Hopkins and Good Samaritan hospitals in Baltimore, Staehlin began seeking others to help.

One of his first successes is the earlier example of the young paralyzed woman who communicates by blinking. Staehlin's "eye-blink writer" has been used to help ten people since it was first developed in 1982, and components for 20 additional systems have been ordered.

Another adaptation developed by volunteers at VME is a modified mobile standing frame for quadriplegics. The modifications made to the existing frame by VME engineers include a tethered waist band which allows the user to sit down or stand up with very little arm pressure, a new braking system and the adaptation of bicycle wheels to make the unit more affordable. Three units are in existence, and VME plans to construct 10 more.

Another early VME project was to improve on a hand-closure device developed by Dr. Siebens to assist patients who could not use their fingers. Through the integration of a small servo-driven motor applying technology similar to that used in the U. S. Air Force F-16 radar, Staehlin and several other engineers made the device less clumsy and more reliable. "Oftentimes, relatively simple devices can make a huge difference in terms of a patient's independence," Siebens said.

VME not only responds to individual needs, but several of its 50 current projects involve research for solutions to particular disabilities. The most ambitious of these is a project to develop a microwave radiating antenna tiny enough to be used for treating brain tumors. A team of seven engineers, including a thermo analyst, has been working with neurosurgeons at the University of Maryland Neuro-Oncol-

This VME modification project enables a quadriplegic to operate this Steiner tractor originally designed for paraplegics.

The VME "eye-blink writer" allows a quadriplegic to control a computer cursor with the blink of an eye.

An early VME innovation is this "Grollman's Trolley," an overhead rail with a hoist and seat to help a bedridden man after whom the device was named to move around his bedroom.

ogy Unit to develop such a device. Staehlin, who is a member of this team, said "thousands could be helped" through medical applications like this.

Outside of the research area, VME's technology applications fall into several basic categories: prosthetic and orthotic devices; transportation and mobility aids; personal assistance devices; employment and educational aids; and communications and sensory aids.

Staehlin has hopes of starting new chapters around the country. To date, he has made presentations to several interested groups: another Westinghouse plant in Pittsburgh; a group of high tech companies in Dallas, including LTV Aerospace and Defense; and a group of aerospace firms in Los Angeles, including TRW, Lockheed, Rockwell International, Hughes Aircraft, Garrett Corporation, Douglas Aircraft, Northrop Corporation, Ford Aerospace, Aerojet General, Lear Siegler, and Litton Industries.

Although none of these companies yet has an organized volunteer network like VME, isolated examples of technological adaptations to aid the disabled can be found in many of them. For example:

• The quadriplegic computer programmer used as an earlier example is an employee of Boeing Computer Services in Seattle. Scientists there have used state-of-the-art artificial intelligence technology to develop the voice-operated workstation. As a programmer, the Boeing employee is able to correspond with others through an electronic mail system and perform business analyses using spreadsheet software. Boeing has plans to create similar stations for other disabled employees in its work areas.

• In 1981, scientists at the United Technologies Research Center in East Hartford, Connecticut, developed a computerized "gait" analysis laboratory at Newington Children's Hospital to improve the way doctors diagnose, treat and rehabilitate patients with such walking disorders as cerebral palsy, muscular dystrophy and polio. The laboratory's computer system uses an infrared camera and small round reflectors attached to the patient's essential joints and muscles to monitor motion, muscle activity and balance.

In addition to donating the services of its scientists, United Technologies provided $200,000 for research and development costs.

• Borrowing technology used to manufacture weight-reduced helicopter tail rotor blades, Sikorsky Aircraft composites engineer Adrian Cooper has developed stronger, but lighter leg braces for victims of muscle diseases. Cooper's brace, developed in conjunction with doctors at Newington Children's Hospital, fits the patient from just below the knees to the feet, and weighs only one-half pound.

• Gene Schell, a structural design engineer for Vought Aero Products Division of LTV Aerospace and Defense Company in Dallas, received a citation from the 1985 President's Volunteer Action Awards for his work in adapting toys for disabled children. One example is the modification of a small tricycle so it could be operated by a child's hands. Schell replaced the pedals with sprockets, a chain and a hand crank.

In addition to the technical work he did, Schell put together an illustrated book of directions for modifying the toys. More than 2,000 copies have been distributed nationwide to agencies and others who work with disabled children.

• Bernie Freund, Chief of Special Purpose Processors for General Dynamic's Convair Division in St. Louis, designed a lightweight, adjustable ankle joint to solve a balance problem for another Convair employee who has an artificial leg. The modification allows the woman to adjust her ankle for two different shoe heel heights.

The PSI-TECH program, according to LTV's Kirk, hopes to develop a plan whereby all these efforts can be organized. "The goal of this public-private sector initiative," he said, "is to develop a national system—a TECH-NET—to use each applied technology to help the maximum number of disabled people. . . . I envision the development of an engineer in Baltimore making life better for individuals in Texas, California and eventually anywhere in the world."

AIA

MEMBERS

Aerojet General
Aeronca, Inc.
Allied-Signal Inc.
  Bendix-Aerospace Sector
  The Garrett Corporation*
Aluminum Company of America
The Boeing Company
Celion Carbon Fibers
  A Division of Celanese Corporation
Colt Industries Inc.
  Chandler Evans Inc.
  Menasco Inc.
  Delevan Corporation
Citron Technologies
E-Systems, Inc.
Ex-Cell-O Corporation
FMC Corporation
Gates Learjet Corporation
General Dynamics Corporation
General Electric Corporation
General Motors Corporation
  Allison Gas Turbine Division
The BF Goodrich Company
Goodyear Aerospace Corporation
Grumman Corporation
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Notable views of notable people on aerospace matters...

aerospace perspectives

Caspar W. Weinberger, *Secretary of Defense, in an address to the San Diego (California) Chamber of Commerce, Rotary Club and World Affairs Council:*

"One of the frequently overlooked realities of the nuclear competition between the United States and the Soviet Union is how fundamentally different are our approaches to this problem. The United States is a democratic and peace-loving society which tends to regard nuclear war as so damaging, so destructive that it is absurd. This notion, in turn, leads to the judgment that somehow nuclear war cannot or will not happen.

"It comes very naturally to Americans to believe all rational beings, including the Soviets, will see it the same way. As a result of this view, too many may feel we can minimize the probability of war through a contract of shared vulnerability. That is what Mutual Assured Destruction is all about. It is, in the words of Fritz Ermarth, our national intelligence officer for the Soviet Union, the strategic equivalent of a price-fixing deal between two competitive firms. But here the price is survival of our society—and one firm is not playing by the rules.

"The Soviets have a perspective on this issue that is entirely different from ours. They believe history is the product of forces gaining ascendancy over other forces. Somebody wins, somebody loses. This does not mean that compromises are not necessary as a tactical expedient, or even as a long term means of controlling certain problems one does not wish to deal with. But in the end, warfare, political struggle and social conflict are—from a Soviet vantage point—not only uncompromising but also inevitable.

"Therefore, the notion of a contract of shared vulnerability, and the notion of an indefinite, stable strategic relationship, are quite alien to Soviet thinking. In short, there is very considerable evidence that the Soviets think nuclear war can be won by them. We, on the contrary, believe that a nuclear war cannot be won and must not be fought. This very different Soviet perspective exerts a strong influence on Soviet strategy and underpins ongoing Soviet strategic offensive and defensive programs."

Manfred R. Hamm, *Senior Policy Analyst, and W. Bruce Weinrod, Director of Foreign Policy and Defense Studies of The Heritage Foundation, writing in Orbis, A Journal of World Affairs:*

"With few notable exceptions, European attitudes toward the Strategic Defense Initiative range from ambivalence and skepticism to outright hostility. It is perfectly legitimate for the allies to question the technological feasibility of SDI and its ramifications for their security . . . But European ambivalence toward SDI reaches far beyond questions of its technical feasibility and strategic impact on their security. It represents an unflinching commitment to Mutual Assured Destruction as a desirable foundation of security, though the assumptions supporting MAD have been eroded by technological developments or disproved by Soviet strategic force programs and doctrinal pronouncements."

Donald E. Fink, *Editor-in-Chief, Aviation Week & Space Technology, in an editorial in that publication:*

"The United States is at an historic juncture with its space program and is in critical need of positive action to end the indecision blocking definition of a coherent policy that will reassert the U.S.'s leadership in space. The trouble is, no champion has stepped forward to seize the initiative, and the ensuing confusion leaves even casual observers wondering whether anyone is in charge of setting the nation's space goals . . .

"A malaise prevades the U.S. space program. The country has gone through an agonizing period, experiencing the catharsis of public investigation and blame fixing. What is needed now is some strong restorative medicine—a clarion call for the U.S. to pull up its socks and get on with the job. What one sees instead is continued indecision and a conservatively paced, if not stodgy, Shuttle recovery program . . . It would be irresponsible to diminish the importance of thoroughly reviewing the Shuttle design and reworking the technical weak points before clearing the next Shuttle for flight. Taking a kick-the-tires, light-the-fires-and-launch approach could ruin the Shuttle program pell mell into another accident that would kill it. But moving along at a sedentary pace with no clear sense of where the Shuttle program is headed or what role it should play in the U.S.'s future space p ns will bring on a hardening of the arteries that will prove just as fatal."

Willard F. Rockwell, Jr., *Chairman of the Board and Chief Executive Officer, Astrotech International Corporation, writing in The New York Times:*

"Outside of the United States . . . efforts to overtake this nation on the frontiers of space are being accelerated. As we contemplate delays, others see glittering opportunity . . .

"Why should we care about space exploration? There are many reasons. It is not a matter of national pride but of national security. It is also a matter of future scientific developments that will affect the health and well-being of our people, our environment, our economy and our place in the world. For beyond the romance of space there are hard and important realities. Those who lead in space will inevitably lead in these other areas vital to our future."

Malcolm T. Stamper, *Vice Chairman, The Boeing Company, addressing the Third NASA Conference on Productivity at Ames Research Center, California:*

"Perhaps the greatest sin American private enterprise ever committed was to create two classes, 'management' and 'labor.' The very terms imply that management doesn't labor and labor doesn't manage. We compound that injustice today by continuing to pay people for their 'time'—in effect 'leasing' labor just as prior generations 'owned' it. It is time indeed to employ people for their minds and spirit as well as their hands, for their participation and good will, not merely their vocation."

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ON THE COVER: Among future missions proposed by the National Commission on Space is reconnaissance of a star other than the Sun. The artwork depicts an automated interstellar spacecraft passing Pluto on its way out of the solar system. In the foreground is Pluto, in the background the moon Charon. Artist: Ron Miller. Copyright 1986 Bantam Books, Inc.

The purpose of AEROSPACE is to:

Foster understanding of the aerospace industry's role in insuring our national security through design, development and production of advanced weapon systems.

Foster understanding of the aerospace industry's responsibilities in the space exploration program.

Foster understanding of civil aviation as a prime factor in domestic and international travel and trade.

Foster understanding of the aerospace industry's capabilities to apply its techniques of systems analysis and management to solve local and national problems in social and economic fields.

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BLUEPRINTS FOR SPACE AND DEFENSE

by KARL G. HARR, JR.
President, Aerospace Industries Association

This issue of *Aerospace* features summaries of two commission reports delivered to President Reagan in midsummer: *Pioneering the Space Frontier*, which lays out a long range space plan developed by Chairman Thomas O. Paine and his National Commission on Space, and *A Quest for Excellence*, the final report of the President's Blue Ribbon Commission on Defense Management, chaired by David Packard. Both are recommended reading, each makes an important contribution, one in prescribing an agenda that would assure continuing U.S. leadership in space, the other in providing a blueprint for stronger defense at lower cost.

Dr. Paine and his commission present an exciting vision of the next 50 years in space, a period characterized by dramatic expansion of space activity culminating, in the 21st century, in large scale settlements on the Moon and on Mars. The program envisioned would engender extraordinary scientific advances, provide a variety of beneficial services to Earth's people, allow production of many products not producible on Earth, and bring large economic returns from new space-based enterprises.

It is an imaginative picture the commission paints, so much so that some have termed it unrealistic. It is, in our view, considerably more realistic, in light of our current technological capability, than the 1961 proposal to send man to the Moon seemed at the time. The impressive credentials of the 15 members of the commission reinforce the belief that the program they recommend is "technically challenging but feasible."

The plan had the bad fortune to appear at a time when the U.S. space program was reeling from the aftermath of the Challenger disaster. In such a gloomy atmosphere, even modest space ambitions seem far-reaching and really dramatic advances seem unattainable. We must shake off that pessimism and recover the "can do" spirit of earlier days—and in that regard the commission's outline of objectives can serve an important purpose as an aiming point for a resurgent U.S. space effort.

For years, the U.S. space program has suffered from lack of clearly delineated long range goals. In this period of restructuring our space program, we have an opportunity to improve the direction, consistency and public appeal of space research by adopting bold, imaginative space goals that demand strong technological push and reward success with great public benefit. The National Commission on Space offers a challenging program that is designed not only to enhance our space capability but to support the broader goals of 21st century America by stimulating advances across a wide spectrum of scientific and technological disciplines.

The report of the Packard Commission serves a more immediate need. It offers a series of recommendations for improving the efficiency and efficacy of our national security system, including the budget process, procurement, legislative oversight and the organization of the Department of Defense, the Joint Chiefs of Staff and the military chain of command.

The aerospace industry is especially supportive of those commission recommendations that deal with the defense acquisition process, among them the need for simplification of excessively rigid military specifications, expanded use of multiyear procurement, increased use of competition that relies on market forces rather than government intervention, and reduction of micromanagement by both the defense establishment and the Congress. The industry particularly welcomes the finding with regard to the widely-publicized "horror stories" which, the commission states, were caused by a variety of inefficiencies in the acquisition process but were "seldom the result of fraud or dishonesty."

The Packard Commission is to be congratulated on an impressively thorough job of investigating the root causes of defense management problems and its clear-sighted blueprint for their solution. We feel that the commission's recommendations—many of them already being implemented—will inspire beneficial change in the management of our defense effort.

THE NEXT FIFTY YEARS IN SPACE

Pioneering the Space Frontier

Within the next half century, there may be large, human-staffed settlements on Mars and on Earth's Moon, along with smaller populations on Earth-orbiting space stations, outposts on the moons of Mars and way stations orbiting between Earth and its Moon.

The people of these extraterrestrial facilities will be engaged in a variety of occupations: conducting scientific observations; operating probes within and beyond the solar system; providing Earth services in advanced communications, navigation, resources monitoring and other areas of benefit not yet apparent; developing new concepts in microgravity laboratories for advancement of Earth-based technology; manufacturing in space and delivering to Earth certain products not producible on Earth; mining extraterrestrial resources and using such materials in robotic factories producing fuel, structures and equipment to support the network of facilities beyond Earth.

Such is the exciting view offered by the National Commission on Space as part of a civil space agenda for the next 50 years. In its report *Pioneering the Space Frontier*, the Commission proposed a triple-thrust program:

- Advancing understanding of the Earth, the solar system and the universe.
- Exploring, prospecting and settling the inner solar system.
- Stimulating space enterprise for the direct benefit of Earth's people.

Accomplishment of these goals, the report said, demands that the U.S. make long-range commitments to two additional thrusts: advancing technology across a broad spectrum to insure timely availability of critical capabilities, and creating systems and institutions to provide low cost access to the space frontier. A first technological requisite is development—for service around the end of the century—of vehicles for moving cargo and passengers to and from low Earth orbit at a small fraction of today's costs. Companion developments proposed for the same time frame are manned, reusable transfer vehicles capable of operating between low and high Earth orbit and between Earth orbit and the Moon. Among later requirements is development of "cycling spaceships," electromagnetically accelerated, very high speed spacecraft for transportation to and from spaceports in Earth, lunar and Mars orbits, together with landing craft for shuttling between the spaceports and the lunar/Mars surfaces.

The Commission believes its program would yield significant payoffs in three areas:

- "By 'pulling through' advances in science and technology of critical importance to the nation's future economic strength and security;
- "By providing direct economic returns from new space-based enterprises that capitalize upon broad, low-cost access to space; and
- "By opening new worlds on the space frontier with vast resources that can free humanity's aspirations from the limitations of our small planet of birth."

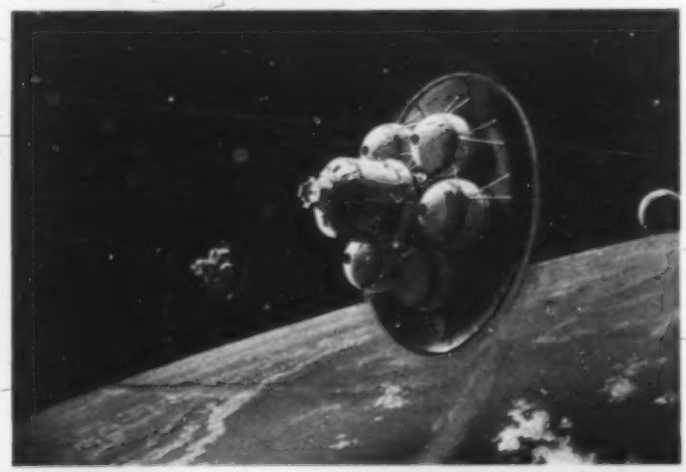
Pioneering the Space Frontier, published by Bantam Books, Inc., New York, is summarized on the following pages and illustrated by a selection of artworks used in the Commission's report. These original artworks, provided to the Commission at no cost to the government, were prepared by noted aerospace artists Robert McCall, Ron Miller and Paul Hudson. They are reprinted herein with permission of Bantam Books (cover and inside art copyright 1986, Bantam Books, Inc.)

The 21st century Earth Spaceport, a growth version of the 1990s Space Station, is receiving supplies from a cargo transport (lower left) while a passenger shuttle from Earth (right) prepares to dock and a manned transfer vehicle (upper right) returning from the Moon approaches the spaceport. *Artist: Robert McCall*

NEAR-EARTH OPERATIONS

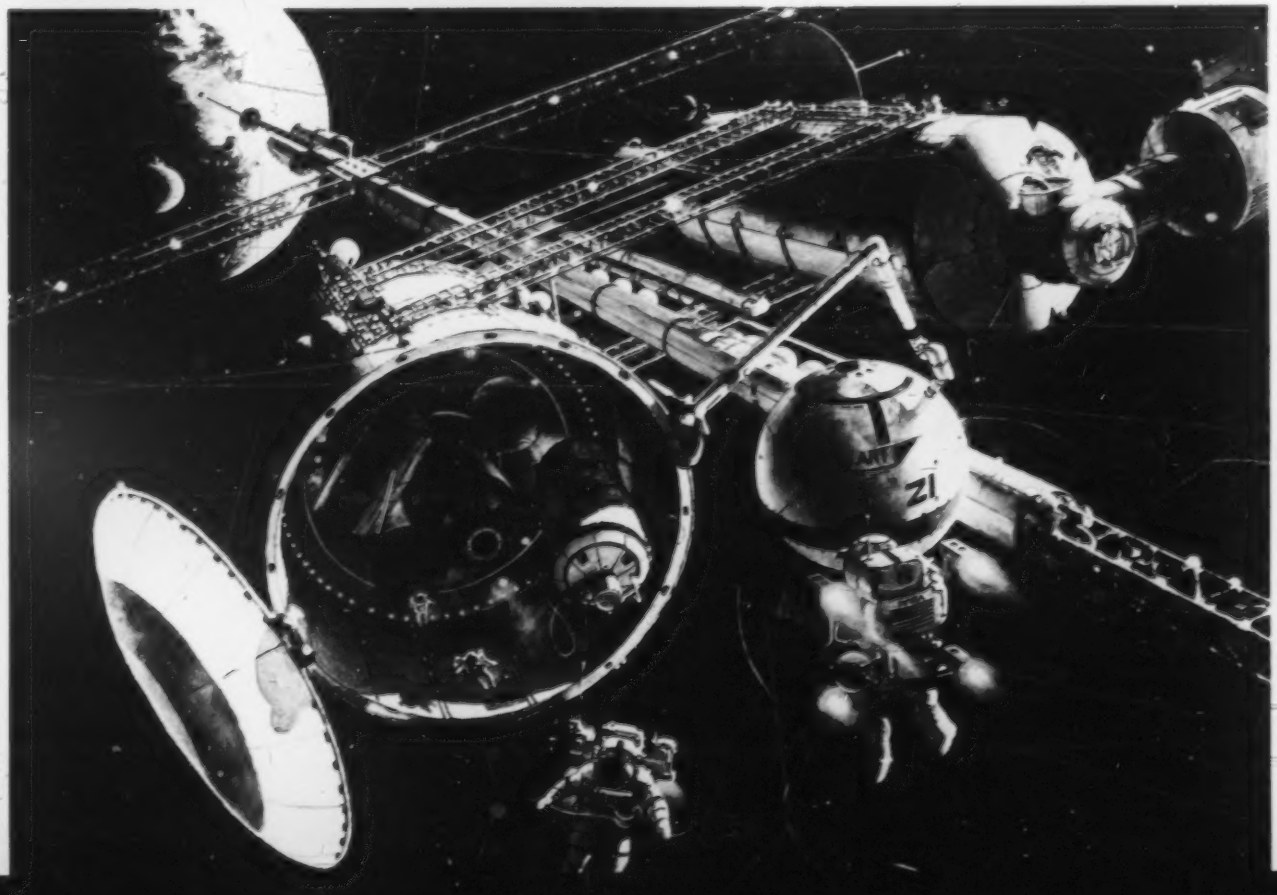
The National Commission on Space assumes that the U.S./international permanent Space Station will be initially occupied in 1994 and that it will gradually expand thereafter until—about 2010—it becomes a full-fledged "spaceport," a large facility capable of supporting regular flights of lunar and interplanetary spacecraft. Beginning early in the 21st century, the Space Station—and later the spaceport—will be linked to Earth by high capacity unmanned cargo vehicles and manned passenger craft. The 21st century near-Earth network will include one or more stations in geostationary orbit (22,300 miles), a variety of unmanned platforms in low Earth orbit, and a number of scientific observatories so large they will be, in effect, auxiliary space stations. All of these facilities will be human-tended.

In addition, there will be a special Variable Gravity Research Facility, an orbiting station dedicated to physiological studies of the long-term effects of low gravity, such as the Moon's one-sixth G and Mars' one-third G. This facility will also conduct R&D on synthetic biospheres—fixed and flyable recycling enclosures for maintenance of human and plant life—that will will be needed for long duration space travel and for human habitation on the Moon and Mars. There will also be space stations at one or more of the "libration points" between Earth and the Moon, five points in space where Earth's gravity is counterbalanced by lunar gravity so that space stations can remain in fixed position without significant expenditure of energy. The whole complex of near-Earth facilities will be interconnected by manned transfer vehicles.



Closeup view of manned transfer vehicles returning to the spaceport. A large ceramic disc at the base or fore end of the transfer vehicle acts as an "aerobrake" to slow the craft as it passes through Earth's upper atmosphere. The cylinder in the center of each vehicle houses passengers; the spheres are propellant tanks.
Artist: Robert McCall

This artist's concept shows a Libration Point Spaceport located between Earth and the Moon, a terminal for huge cycling spaceships shuttling continuously between near-Earth and Mars.
Artist: Robert McCall



EXPLORING AND PROSPECTING

Mars and its satellites, Earth's Moon and orbiting space facilities will provide platforms for scientific observatories and launch bases for unmanned probes to the outer planets and the stars. Major effort will be devoted to assessment of resources on the bodies of the solar system—water, hydrocarbons and materials that can be processed to create propellants, structures, radiation shielding and manufactured products for the network of bases beyond Earth.

Initial exploration and resource assessment will be carried out by robotic prospectors that will employ remote sensing and on-site measurements to discover and characterize usable materials. Samples of promising materials will be returned to Earth—or to extraterrestrial laboratories—for use in development of ways to process the materials. Areas of the Moon, Mars and the most accessible asteroids will be further explored and surveyed by robot-aided human teams.

The next visitation in the U.S. program of exploring the planets of the solar system will be the 1989 Voyager 2 flyby of Neptune. In the foreground is Neptune's moon Triton. *Artist: Ron Miller*

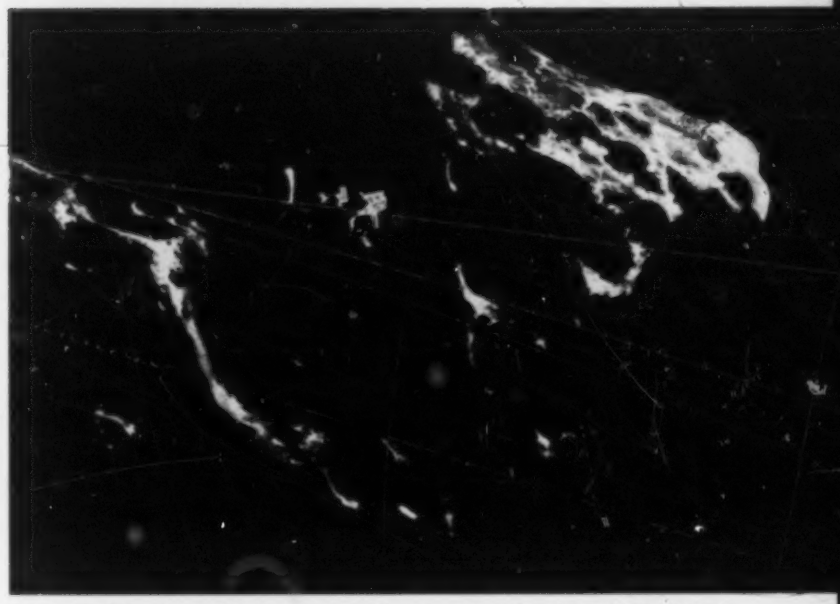
The Commission recommends an early 21st century mission to the nearest star by a long-life, high velocity spacecraft. Here a starbound spacecraft speeds past Pluto on its way out of the solar system; in the background is Pluto's moon Charon. *Artist: Ron Miller*

Along with analysis of returned samples, instrument measurements of the planets and moons will provide critical information about cosmology and planetary evolution. In this concept, a 21st century probe is descending into the atmosphere of Titan, a moon of Saturn. *Artist: Ron Miller*

COMETS AND ASTEROIDS

In addition to comprehensive exploration of the planets of the solar system—including Earth—the space science program recommended by the Commission includes acquisition of samples from some of the "small bodies" of the solar system—comets and asteroids. It is quite possible, the Commission said, that the primitive materials which accumulated to form celestial bodies are still preserved in essentially their original form within comets, hence offer incalculably important scientific information.

Asteroids are also of scientific interest, but they may prove more important as sources of materials that can be processed to provide supplies for support of extraterrestrial bases. A special group of asteroids, almost unknown until the past decade, holds particular promise for exploration and resource utilization: members of the "Earth crossing" group, whose orbits bring them closer to the Sun than Earth itself. The Commission proposed expanded searches for readily accessible asteroids, continued telescopic characterization of their surfaces, and prospecting missions to the most promising.



An automated spacecraft makes a reconnaissance of an asteroid. *Artist: Paul Hudson*

In the 21st century, asteroids deemed promising on the basis of unmanned spacecraft data will be explored by human crews to confirm the presence of usable resources. In this concept, an astronaut is departing a transfer vehicle for a surface look at an asteroid. *Artist: Robert McCall*

LUNAR ACTIVITIES

By the year 2005, according to the Commission's report, the U.S. will build a manned outpost on Earth's Moon and within a few years thereafter begin operation of a pilot plant producing propellants. By 2020, the Commission expects a full-fledged lunar colony with extensive manufacturing capability. Prior to that time, perhaps about 2105, there will be a spaceport in lunar orbit, from which Moon products and materials—brought up from the surface by shuttle vehicles—will be transported to other destinations in the extraterrestrial network.

The lunar colony's work will be in part scientific, in part resources processing. Scientifically, the Moon affords an excellent base for astronomy, both optical and radio. Large optical telescopes can record celestial images free of the blurring effect experienced by Earth telescopes due to atmospheric distortion. The far side of the Moon offers ideal locations for siting radio astronomy systems, shielded from Earth radio interference by 2,000 miles of rock.

The Apollo lunar landing program provided considerable information on Moon resources available for processing. They include oxygen and hydrogen, extractable from lunar soil and rock; material for rocket fuels and shielding from radiation; raw lunar glasses that can be processed to become strong composites for extraterrestrial structures; and silicon for power-generating solar arrays.

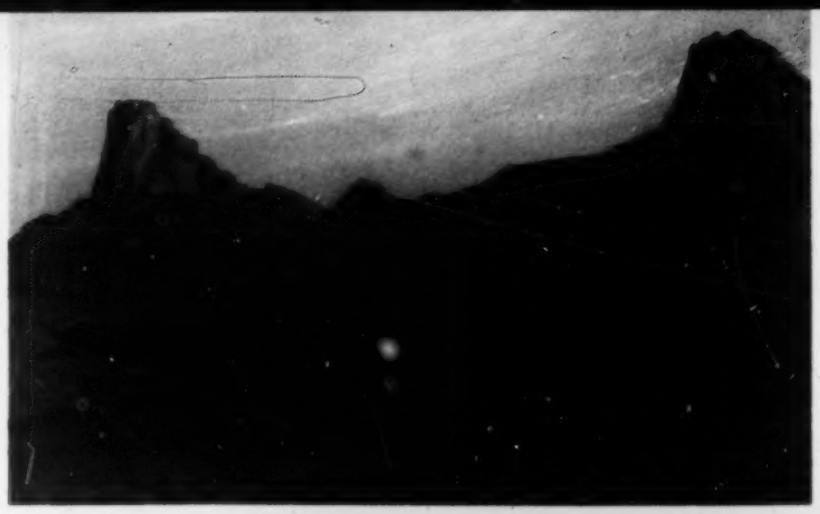
A 21st century lunar settlement. *Artist: Robert McCall*

Principal lunar activities will be astronomical research (note observatory at upper left), mining and product manufacture. In the foreground, a mass driver is propelling pieces of raw lunar material into a trajectory for their collection and use at other extraterrestrial facilities. *Artist: Robert McCall*

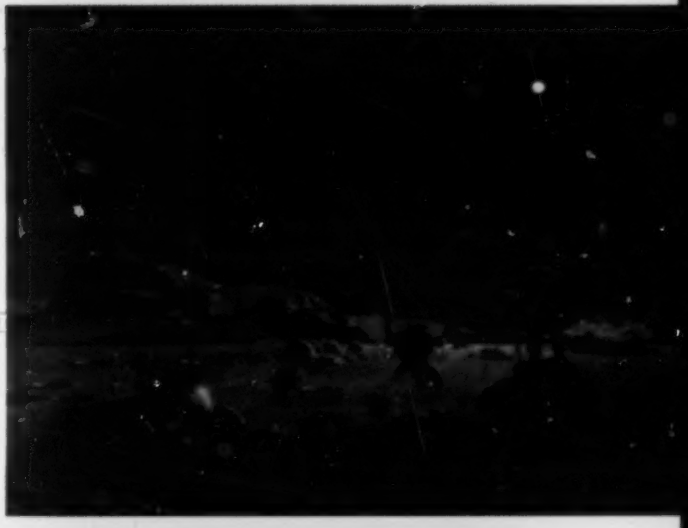
MARS ACTIVITIES

The Commission sees an eventual need for a permanent settlement on Mars, which, after the Moon and the accessible asteroids, is the next easiest place in the solar system to reach and the only planet hospitable to human habitation. In the early 21st century, man will establish a base camp on the Martian surface, or possibly on the Martian moon Phobos. The Commission's suggested timetable: first human-staffed outpost, about 2016; initial permanent base and Mars spaceport, 2022; and "full base," or Martian colony, about 2028.

Activities on Mars will parallel those of the Moon—astronomical, medical and planetary research, plus prospecting, mining and manufacturing. The colonists will live in enclosed biospheres that allow food growth, permit recycling of air and water, and provide shielding from radiation. They will explore the planet by means of robotic rovers or manned rocketplanes. Because they will necessarily be long duration residents, the 21st century space frontiersmen may have to be provided artificial gravity. It is expected that the essential techniques for creating a partial gravity in the biosphere habitats will earlier have been developed at lunar laboratories or the Variable Gravity Research Facility in Earth orbit.

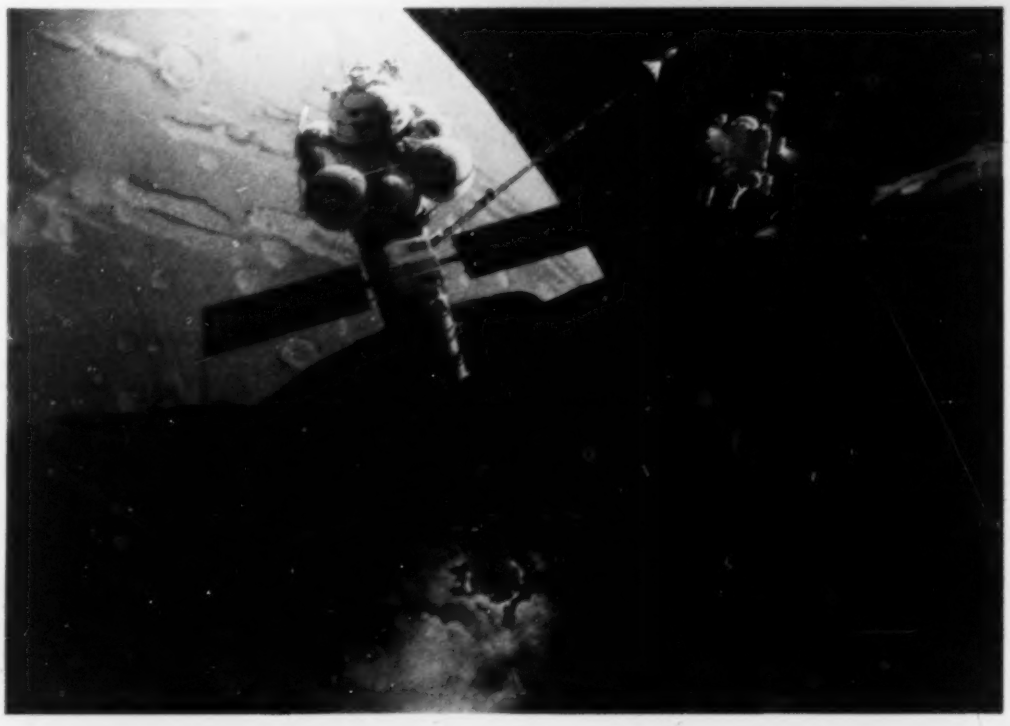


Artist's concept of a possible joint U.S./Soviet unmanned mission to Mars, in which the U.S. would build the robotic roving prospector and the Soviets would provide a spacecraft to return collected samples to Earth.
Artist: Ron Miller



A 21st century Mars settlement with a shuttle lander arriving from the Mars Spaceport (foreground) and another departing (background).
Artist: Robert McCall

Mining propellant material on Phobos, a moon of Mars.
Artist: Robert McCall



Blueprint for Improved Defense Management

A QUEST FOR EXCELLENCE

"Excellence in defense management will not and can not emerge by legislation or directive. Excellence requires the opposite—responsibility and authority placed firmly in the hands of those at the working level, who have knowledge and enthusiasm for the tasks at hand. To accomplish this, ways must be found to restore a sense of shared purpose among Congress, the Department of Defense (DoD) and industry. Each must foresake its current ways of doing business in favor of a renewed quest for excellence."

With these words, Chairman David Packard succinctly summed the prescription of the President's Blue Ribbon Commission on Defense Management for improving the administration of national defense. Packard's remarks are contained in the foreword to *A Quest for Excellence*, the Commission's final report to the President, which covers the findings of a year-long "broad and searching look" at defense issues and the root causes of defense problems.

Solving those problems and building an armed force of "utmost strength and readiness" will require a rededication by all concerned to some basic principles of management. Chairman Packard spelled out the major requirements:

"Congress must resist its inveterate tendency to legislate management practices and organizational details for DoD. Excellence in defense management will not come from legislative efforts to control and arrange the minutest aspects of DoD's operation. Congress can more usefully contribute by concentrating on larger, often neglected issues of overall defense posture and military performance.

"DoD must displace systems and structures that measure quality by regulatory compliance and solve problems by executive fiat. Excellence in defense management can not be achieved by the numerous management layers, large staffs and countless regulations in place today. It depends, as the Commission has observed, on reducing all of these by adhering to basic, common sense principles: giving a few people the authority and responsibility to do their jobs, maintaining short lines of communication, holding people accountable for results.

"Defense contractors and DoD must each assume responsibility for improved self-governance to assure the integrity of the contracting process. Excellence in defense management will not be achieved through legions of government auditors, inspectors and investigators. It depends on the honest partnership of thousands of responsible contractors and DoD, each equally committed to proper control of its own operations."

Contractor Codes of Ethics

The Commission considered the matter of improved contractor/DoD self-governance so important that it published a separate report entitled *Conduct and Accountability*. That report states: "Contractors will be required to do much more than they have done in the past to comply with contractual, regulatory and statutory standards, and to provide adequate supervision and instruction for employees." The Commission suggested that corporate controls could be greatly improved in at least three fundamental areas: development of codes of conduct addressing problems and procedures incident to defense procurement; promulgation and enforcement of more effective control systems to ensure compliance with those codes; and establishment of a more effective oversight of the entire process by an external independent committee.

These recommendations, first advanced in the Commission's February 1986 *Interim Report*, were amplified by Chairman Packard at a May meeting with a group of defense industry leaders in Hot Springs, Arkansas. Packard's proposal that defense industry develop and implement its own Code of Ethics and Conduct met with instant acceptance by the industry group.

Aerospace Industries Association (AIA) led the way in responding. Only two weeks after the Hot Springs meeting, AIA's Board of Governors directed that the association's bylaws be amended to require that membership in AIA be contingent upon a company's adoption of an appropriate code of business ethics and conduct. (A survey made prior to that action indicated that the great majority of AIA member companies already had ethics programs in place or were developing such programs.) In June, AIA's Executive Committee considered a set of Defense Industry Initiatives on Business Ethics and Conduct and passed a resolution accepting them as the guidelines and principles to be employed in implementing individual company codes. Shortly thereafter, the initiatives were adopted by 32 major companies (27 of them AIA members) whose combined defense sales represent about half of the total defense procurement. In announcing that development, Chairman Packard stated that "the industry has gone further and moved faster than I ever thought it would." He expressed confidence that most other companies in the defense industry would join in this endeavor.

All of the signatories to the Defense Industry Initiatives document pledged to abide by six principles: each company will adhere to a written code of ethics and conduct; establish standards of conduct and train employees concerning their personal responsibilities under the code; create a "free and open atmosphere" to encourage employees to report code violations without fear of retribution; govern itself by monitoring compliance with federal procurement laws and voluntarily disclosing violations; accept a responsibility to other companies for preserving the integrity of the defense industry as a whole; and be accountable to the public.

The latter item means that each company's independent public accountants will be required to complete a detailed annual questionnaire, the answers to which will enable evaluation of a company's efficacy in adhering to the code.

The questionnaire will be analyzed by an external independent body—the nature and composition of which will be announced soon—and that group will simultaneously release to the defense contractors and to the general public an assessment of how well industry self-governance is working. This annual public accountability review, to be conducted for each of the next three years, is intended to lend credibility to the initiatives and the defense industry's efforts to maintain high ethical standards.

The industry's ethics program, one of the first Packard Commission recommendations to be put into effect, is regarded as a very important step toward improving defense management," said the Commission's final report. "We are convinced that significant improvements in corporate self-governance can redress shortcomings in the procurement system and create a more productive working relationship between government and industry."

Defense Acquisition

Another area of special Commission focus, also the subject of a separate report, was the acquisition of defense equipment. The Commission concentrated its attention not on the widely publicized spare parts horror stories but on major weapon system programs wherein greater efficiency can lead to large-scale cost savings. It did, however, look at the spare parts question, not as a focal point of acquisition problems but as a symptom of "a system more fundamentally ill." The final report stated:

"Although each of the (spare parts) cases we examined had its own peculiarities, we identified a number of problems that frequently recurred: for example, government insistence on rigid custom specifications for products despite the commercial availability of alternative items costing much less; the ordering of spare parts so late in a program, after the close of the production line, that they must be expensively hand-tooled; the use of unsuitable cost-allocation procedures that grossly distort the price tags of inexpensive spare parts; the buying of spare parts in uneconomically small quantities and hence at higher prices; and the simple exercise of poor judgment by acquisition personnel. In general, we discovered, these problems were seldom the result of fraud or dishonesty. Rather they were symptomatic of other underlying problems that affect the entire acquisition system."

Among a variety of deeply entrenched problems that "have developed over several decades from an increasingly bureaucratic and overregulated process," the Commission cited the manner in which military requirements for new weapons are established, "goldplating," or including in a new design features that are desirable but more expensive than their operational value warrants; unrealistic estimates of cost and schedules; the contractor bidding and selection process; and, once a project is launched, the difficulties associated with managing an "overspecified and underfunded program." To quote the report: "An army of advocates for special interests descends on the program to ensure that it complies with various standards for military specifications, reliability, maintainability, operability, small and minority business utilization, and competition, to name a few. Each of these advocates can demand that the program manager take or refrain from taking some action, but none of them has any responsibility for the ultimate cost, schedule or performance of the program."

The Commission's basic recommendation in this area was a general streamlining of acquisition organization and procedures under the leadership of a new Under Secretary of Defense (Acquisition); legislation creating such a post has been enacted into law. Among other recommendations were high priority on testing prototype systems to demonstrate the capability-enhancing and cost-reduction prospects of new technology; steps to improve program stability, including giving the program manager full authority; greater purchase of commercially available "off-the-shelf" components and systems; increased use of competition that relies on market forces instead of government intervention; and improvement in the quality of acquisition personnel.

In addition to acquisition and conduct/accountability, the Commission probed in depth two other broad areas of defense management: the national security planning and budgeting process, and military organization and command. Chief among recommendations related to planning/budgeting was establishment of a five-year defense plan and a two-year defense budget, to obviate the traditional year-to-year Congressional approval which "reinforces DoD's own historical penchant for defense management by fits and starts." The Commission also proposed a number of changes relative to the organizational structure and chains of command within the defense establishment.

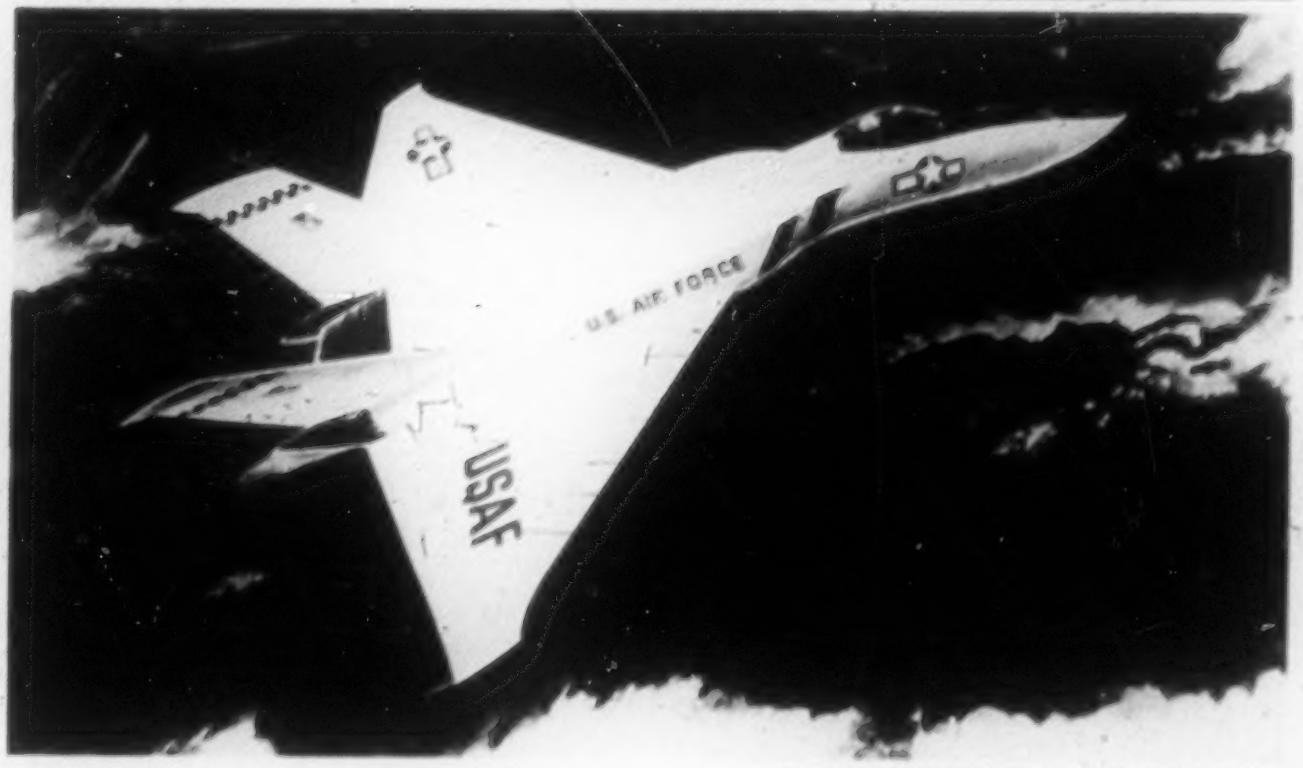
The well-received reports of the Packard Commission promise large-scale beneficial changes in defense management for the long term. Many of the recommendations, such as contractor ethics programs and acquisition streamlining, are already being implemented. Even before the final report was published, President Reagan directed DoD and other agencies to put into effect virtually all of the recommendations in the Commission's *Interim Report* that did not require legislation. The President also sent Congress a Special Message requesting early enactment of the requisite legislation; much of it has already been passed.

It is, said the Commission, "a promising beginning but much more remains to be accomplished." In the words of *A Quest for Excellence*: "It is only through a willingness to change by both public and private institutions that our recommendations will achieve their ultimate purpose of restoring stability, saving money and fielding better military forces."

★

ATF: Tomorrow's Superplane

By JAMES J. HAGGERTY



An Air Force concept of the Advanced Tactical Fighter, a planned air superiority fighter for the 1990s and beyond

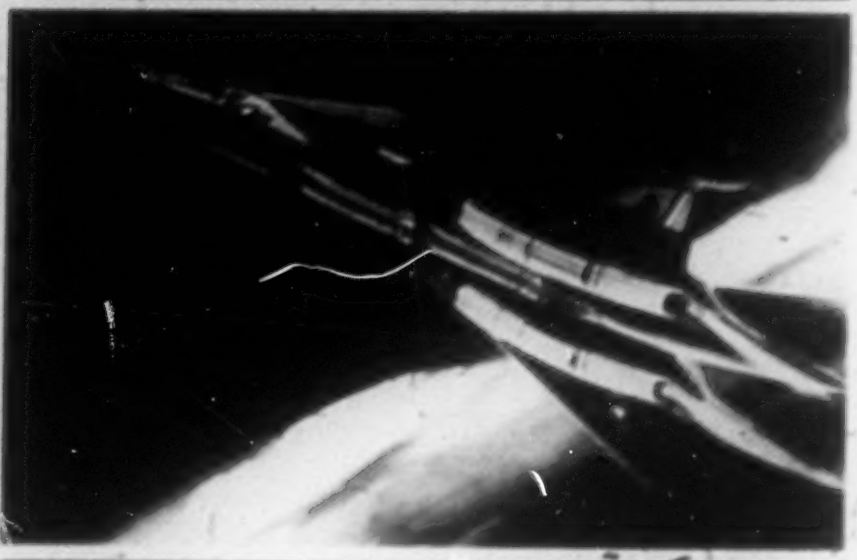
The bottom line in American fighter development is to build a system that lets the pilot win in combat because he's free to fly the mission, not the plane," says General Lawrence A. Skantze, Commander, Air Force Systems Command (AFSC).

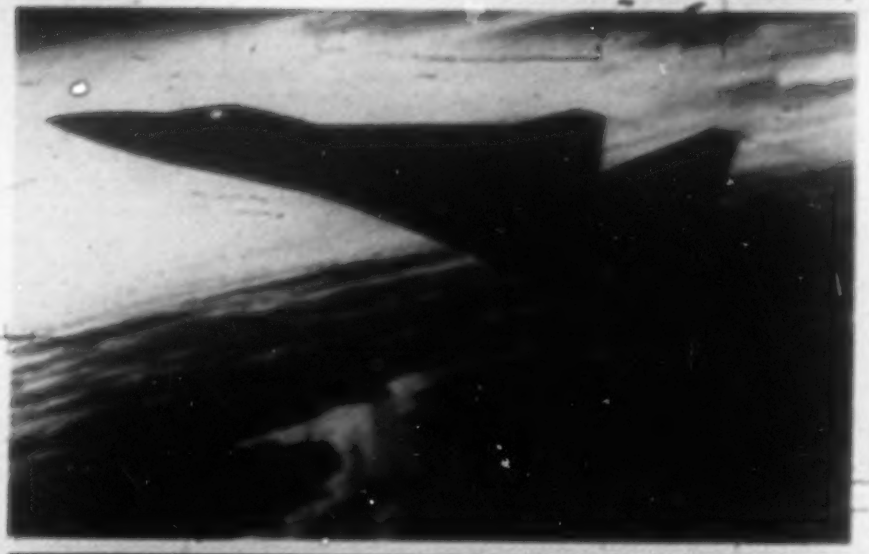
The airplane he's talking about is the USAF's planned air superiority fighter for the 1990s and beyond, the Advanced Tactical Fighter, or ATF. The acronym is not yet a household term among the general public but it will become very familiar in coming years because the ATF program represents a giant leap in aircraft development, a high production system of extraordinary importance to the overall defense plan, and a trailblazer of new techniques in the weapons acquisition process. Designed to engage and destroy enemy aircraft over their own territory, it will be capable of *sustained* supersonic flight, where current fighters are only briefly supersonic, and it will have unprecedented maneuverability. Its high degree of artificial intelligence will literally allow the pilot to communicate with the airplane. Advanced stealth technology will make it minimally visible to adversary detection systems. And a variety of other new technologies in avionics, propulsion, structures and flight control will combine to allow ATF pilots, as General Skantze put it, "to fight and win outnumbered, and do it in the enemy's back yard."

In October, the ATF program will mark a major milestone when the USAF selects airframe contractors for a multiyear Demonstration/Validation phase, which involves construction and test of flight vehicles and ground avionics prototypes. The competitors include The Boeing Company, General Dynamics Corporation, Grumman Aerospace Corporation, Lockheed-California Company, McDonnell Douglas Corporation, Northrop Corporation and Rockwell International Corporation.

Each of these companies had earlier conducted ATF conceptual design studies, beginning in September 1983. In July/August of this year, each submitted technical and cost proposals for the Demonstration/Validation effort to AFSC's Aeronautical Systems Division, whose ATF System Program Office is evaluating the proposals. The latter office will narrow the seven airframe concepts to two and award contracts for flight and avionics prototypes. Competitive flight testing is planned for 1990.

Engine development is proceeding on a separate course. In September 1983, Aeronautical Systems Division awarded contracts to Pratt & Whitney Aircraft Group and General Electric Company for parallel development of an ATF engine described as "a quantum leap in itself." The engine will be in the 32,000 pound thrust class, feature supersonic cruise with high efficiency, new internal geometry, materials and controls and an advanced nozzle concept. A particular requirement is exceptionally high relia-





The Boeing Company (top), General Dynamics (center) and Lockheed-California (bottom) concepts of the ATF. The three companies submitted separate proposals but will work as a team on design, production and support of the ATF if any one of the proposals is accepted by the Air Force.

bility and maintainability. Says General Skantzer: "Given the U.S. numerical disadvantage, it's a simple deduction that we'll have to fly the fighters we have more often to defeat the adversary. We can't afford to build a superplane like the ATF and have it become a 'hangar queen'. So designing in reliability and maintainability are top priorities."

General Electric and Pratt & Whitney will have ground demonstrator engines running by the end of this year. Extensive testing of the demonstrators will feed development of prototype flight engines, work on which has already begun.

From these airplane, engine and avionics competitions over the next five years will emerge one ATF design that will become the basis for a large-scale production program of the aircraft that will serve as the USAF's air superiority fighter from the mid-1990s to well into the 21st century. As for the engine, the Air Force is keeping its options open; it may select one ATF engine or it may decide to take both into production and compete one against the other.

If an airframe contractor loses out in the October selection, the company may still play a big role in the ATF program under a teaming process. Boeing, General Dynamics and Lockheed have signed a teaming agreement whereby, if one of the three is awarded a Demonstration/Validation contract, it will become the team's prime contractor and the other two will work as subcontractors. McDonnell Douglas and Northrop have announced a similar arrangement. Grumman Aerospace and Rockwell International are studying teaming; either may form a team if it is declared a winner, or otherwise it may join another cooperative effort. Other aerospace companies, not directly involved in the airframe concept proposals, are interested in becoming subcontractors. It seems likely, from the scope of the program, that a large segment of the aerospace industry will eventually be involved in the ATF.

"The Air Force has strongly encouraged teaming," says Colonel Albert C. Piccirillo, director of the ATF System Program Office. "Fixing together all these advanced technologies in the ATF is a giant challenge. It will take a lot of technological resources, not just for development but for affordable productibility. Teaming gives us a broader pool of resources we can bring to bear, the combined technical and management resources of two or more companies instead of a single contractor. We think it will get us a better system." Teaming also expands the funding available for technology development as companies invest their own money for competitive reasons, and it broadens the industrial base for stepped-up production of the ATF should that become necessary.

The need for an ATF stems from what

McDonnell Douglas and Northrop, teammates on the Navy F/A-18 program, will again team on the ATF if either company's conceptual proposal wins a contract. The McDonnell Douglas design is at left, Northrop's at right.

the Air Force describes as a "formidable assault" by the Soviet Union, over the last 15 years, on what once appeared to be an insurmountable U.S. technological lead in fighter aircraft. Throughout the 1970s, the Soviet aircraft performance curve moved steadily upward and by the early 1980s the USAF is convinced, the USSR had "definitely arrived" as a builder of high quality, high technology fighters. Their latest can match performance and weapons capabilities with the Air Force's McDonnell Douglas F-15 and General Dynamics F-16. "Add to those capabilities sheer numbers," says AFSC's General Skantze. "If we had the Soviet rate of fighter production we could replace the active U.S. Air Force inventory every year and a half."

In addition to contending with superior numbers of enemy fighters, tomorrow's ATF pilots will have to operate in an extremely dense surface-to-air threat environment. The Soviets have more than 10,000 air surveillance radars providing good coverage at low altitude and virtually complete coverage at medium and high altitude. They have some 4,600 tactical surface-to-air missile launchers, all mobile, and 12,000 antiaircraft guns, also mobile. In their research and development effort, they are improving surveillance, identification, target tracking and fire control capabilities, and they are developing more advanced surface-to-air weapons, one, now in flight test status, will be able to intercept aircraft at all altitudes. The Soviets could also, the USAF believes, deploy short range tactical defense laser weapons soon. Finally, they are producing surface-to-air weapons at the rate of 40,000 units a year—15 times that of U.S. production.

Thus, the challenge is to develop a superfighter that can concede a big numerical advantage, penetrate and survive the Soviet ground-to-air threat, and defeat the best tactical aircraft the Soviets can field in the 1990s and beyond.

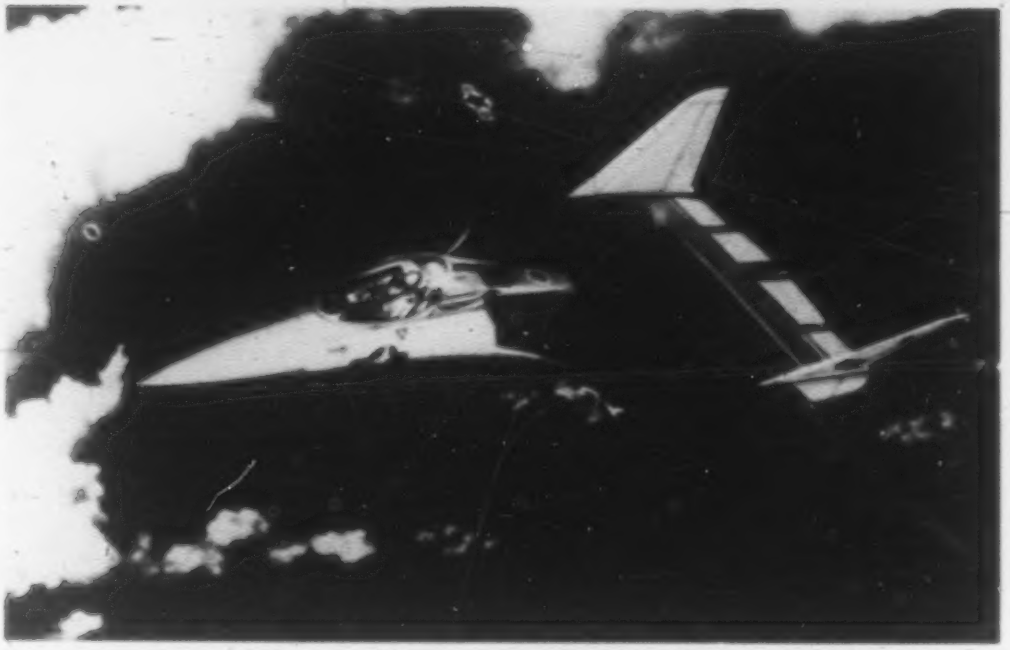
The Grumman Aerospace ATF concept features the forward swept wing already being flight tested in the Grumman built X-29A research aircraft.

Clearly, General Skantze points out, we're not developing a fighter that just offers a single dimension increase in reliability and capability. We need a revolutionary system that dominates the first quarter of the 21st century.

A big order, but attainable if a number of emerging technologies can be simultaneously brought to maturity and integrated into one flying machine. That's the AFSC plan for the ATF. In 1982, the Air Force Scientific Advisory Board studied technologies that offered high payoff in combat capability and could be expected to mature by the end of the decade. Among the advances that the USAF plans to incorporate in the ATF are:

- Propulsion and aerodynamic technologies for sustained supersonic flight, exceptional maneuverability and general performance far exceeding that of current fighters.
- Short takeoff and landing technologies to reduce runway dependence.
- Low observables technology (stealth) to mask the ATF's radar and infrared signatures and thereby reduce the airplane's vulnerability to both fighter and ground-launched missile attack.
- An integrated electronic warfare system that will reinforce the ATF's ability to penetrate enemy airspace undetected, with very high speed integrated circuits (VHSIC), it will require only about one percent of the circuitry used in current aircraft electronic systems, which means fewer cables, fewer connections, fewer failures.
- Advanced composite materials technologies for stronger, lighter, more durable structures.
- A self-repairing flight control system that would allow the ATF to complete its mission even when badly damaged.
- New engine materials technologies that will afford a 150 percent improvement in parts life over the currently most

ATF



Rockwell International's concept of the ATF. Rockwell, like Grumman, had made no teaming arrangement at proposal submission time (August) but may later

advanced engine, 40-60 percent fewer parts, 60 percent fewer specialized maintenance tools.

- Built-in test features that will enable the aircraft to identify its own maintenance problems, allowing reduction of downtime and ground crew requirements.
- Computerized artificial intelligence that sifts and prioritizes a mass of sensor information to give pilots fast decision options in battle.
- Helmet-mounted displays/sights and computerized voice recognition technology that will obviate the need for the pilot to take his hands off the controls or take his eyes off the target; instead of toggling switches, he will be able to vocally ask his aircraft to display certain information on his visor and he will verbally instruct the plane as to armament selection and fire control modes.

The problem with integrating so many advanced technologies still being developed is that each represents an element of risk and together they constitute a very large risk factor. To reduce the risk, the Air Force is conducting an innovative acquisition program, based in part on the recommendations of the Packard Commission (see page 8), that involves "fly before buy" prototyping and greater-than-customary competition prior to full scale development.

The Packard Commission report stated: "A weapon system should be predicated on state-of-the-art technology when the benefits of the new technology offset the concomitant risks. This principle, easy to state, is hard to apply because of the difficulty of getting reliable information with which to make the tradeoff of risks and benefits. The only consistently reliable means of getting such information is by building prototypes that employ the new technology."

When the Packard Commission recommendations were made available to the Air Force about the beginning of this year, the USAF heeded the advice and revised its game plan for ATF development. Under the restructured program, mission and technology requirements will be identified, costs assessed, risks reduced and the design debugged—all before full scale development begins. The key to this approach is construction, by each of the two contractor teams selected, of both flight prototypes and avionics prototypes. The flight program will start earlier than originally planned—1990 instead of 1992—and the fight test data will be incorporated in design refinements before the USAF must commit the major share of ATF funding for full scale development. Similarly, extensive ground testing of the avionics prototypes will resolve uncertainties about the very advanced electronics features contemplated, which represent the greatest area of technical risk.

Prototyping in the Demonstration/Validation phase is obviously far more expensive than validating a design by computer simulation and wind tunnel testing, so the Air Force will have to spend more in the immediate years of the ATF program—the next three fiscal years. However, the USAF expects to recoup the upfront investment with interest—and get a better system in the bargain—by determining the final design and accomplishing the risk/performance tradeoffs earlier in the program. The Air Force believes that a lower risk full scale developmental effort, with greater concentration on productibility, may ultimately reduce the total program cost.

With several hundred aircraft planned for the air superiority role in the latter 1990s and the 21st century, and with the possibility of other production versions, the ATF is a "big ticket" program. The Air Force is placing heavy emphasis on curbing costs, but it recognizes that pushing the frontiers of aeronautical technology is necessarily expensive. AFSC's General Skantze states that "The plane must be affordable . . . but affordability is a two-edged sword.

"On one side, we've got to deliver the ATF at a dollar value that's acceptable to the Congress and the Air Force. On the other, we've got to give it sufficient technical advantage over the projected Soviet threats to fight outnumbered and win. That costs money.

"The challenge is to sharpen both edges at the same time. Affordability is more than a straight fiscal issue. It asks more than 'How many ATFs can we buy based on R&D costs, unit costs and annual production rate?' These costs are important . . . but the affordability question is also a national security issue. 'What technologies and how many planes *must we afford* for a fighter force that meets and defeats the threat?'

A design engineer for Hamilton Standard's Space and Sea Systems department, Gail Smith, 24, is shown here as a test subject for the Hamilton Standard-built Extravehicular Mobility Unit.

Kathryn L. Williams supervises Aerojet Electro Systems Company's ground station Software Development Group.

Dana B. Badgerow is Vice President, Contract Management for Honeywell, Inc. for its Aerospace and Defense business unit. She feels contract management in the aerospace industry offers a ripe opportunity for women with law degrees.

Dr. Dora Daugherty Strother (Mrs. Lester Strother) B-29, glider, helicopter pilot, former WASP, a Lt. Colonel in the USAF Reserve, a licensed psychologist in Texas and a member of the Army Science Board is Manager, Human Factors Engineering and Cockpit Arrangement Group at Bell Helicopter Textron.

Linda Schnetzler is a senior human factors engineer at the Lockheed-Georgia Company.

At Rockwell International's Science Center, Dr. Margaret Brown is on the technical staff of the Infrared Materials Department. Here she seals a cadium telluride sample for growing a crystal.

NASA-Ames Laboratory assistant Leah Schafer is strapped into a vertical acceleration device by Dr. Patricia Cowings' research psychologist. Dr. Cowings trains subjects in the use of biofeed back to prevent motion sickness.

WOMEN IN

By JEAN ROSS HOWARD

In 1952, there were 52 women graduates of U.S. engineering schools. As recently as 1975, women accounted for only 878, or 2.3 percent, of engineers awarded degrees. But in the last decade women have made dramatic inroads into the engineering profession. In 1984, they numbered more than 10,000 engineering school graduates, 14 percent of the total.

Those statistics represent one indicator of a still-growing trend, the proliferation of women in occupational areas once almost exclusively the province of males. The trend is particularly evident in the high technology aerospace industry, where women hold key positions in top level corporate management, as engineers, scientists, lawyers, sales and marketing representatives and, in operational jobs, as pilots and astronauts. In engineering, aerospace women are designing weaponry, aeronautical and space systems; they are engaged in a broad range of disciplines that includes ceramic, environmental, structural, research, flight test, industrial and manufacturing engineering.

The Bureau of Labor Statistics reports that engineering employment will increase 36 percent through 1995, adding 480,000 jobs. Nearly all will be electronic and electrical engineers, developing computer, telecommunications and defense equipment. It is estimated the U.S. will need more than 600,000 new engineers between now and the year 2000—50 percent more than industry now employs.

The government Office of Technology Assessment concluded in a December 1985 study that to continue to keep American competitive and strong in defense, the nation must find ways to expand the engineering labor pool. The report cited the need to utilize human resources to the fullest, especially those groups with historically low participation rates in science and engineering—such as women.

Many corporations, particularly aerospace firms, share this opinion and are doing something about it. On the college level, industry helps fund the National Merit Scholarships and others, provides grants to universities and offers scholarships to families of employees. Typical of industry

participation is Northrop Corporation, whose divisions are developing and sponsoring dozens of programs for young engineers, some targeted specifically for women. They range from teacher enrichment services to one-of-a-kind job training programs. In addition, Northrop and the California State University at Northridge sponsor an unemployed or underemployed woman with a baccalaureate degree in a science and give her a part-time paying job while she earns an engineering degree.

For high school seniors, Westinghouse Electric Corporation has – for 45 years – sponsored the annual Westinghouse Talent Search Scholarships. Of the 300 honorees (boys and girls) selected across the country, 40 finalists are brought to Washington, D.C. to receive scholarships ranging in value from $1,000 to $20,000.

So many and so diversified are the jobs performed by women in aerospace today that available space precludes all but a representative selection of examples. Here is a sampling of what women have done and are doing to help advance U.S. technology and leadership in aerospace.

GOVERNMENT

- In the federal government, as Secretary of the Department of Transportation which includes both the U.S. Coast Guard and the Federal Aviation Administration, Elizabeth Hanford Dole is the top woman in U.S. aviation.

AEROSPACE

- At the FAA, the Deputy Director of the Technical Center is fixed wing pilot Arlene Feldman and air traffic controller Kate Beebe is president of the Professional Women Controllers. Another fixed wing pilot, Carol Rayburn, is Manager of the General Aviation/Commercial Division.
- At NASA, Anne Bradley is Associate Deputy Administrator; Lanea M. Couch is Deputy Director, Information Sciences & Human Factors Division; electrical engineer Dr. Carol Roberts is acting Deputy Director of the Information Science and Human Factors Division; and Shirley Green is Director of the Office of Public Affairs. In January 1978, six of the 35 astronaut candidates selected were women. Today, there are 12 female astronauts.

INDUSTRY

- At Aerojet General's Aerojet TechSystems Company, Dr. Liselotte Schioter develops creative uses for ceramics and other high temperature materials in liquid rocket engines. "In less than a quarter of a century," Dr. Schioter points out, "ceramics have evolved from toilet bowls and ashtrays to become the heat resistant tiles on the Shuttle."
- Aerojet engineering specialist Nancy R. Shimp uses her command of the sophisticated computer aided design (CAD) network for designs that used to take months on a drafting board. Using CAD, they take about three weeks.
- Dr. Ellen R. Domb, manager of Aerojet's Demonstration and Technology Department, is investigating the design validity of advanced infrared space surveillance systems for Strategic Defense Initiative (SDI) related contracts.
- In Aerojet's Research Engineering Department, Dr. Patricia M. George is responsible for the design, construction and evaluation of the company's Surface Science Facility.
- At General Motor's Allison Gas Turbine Division, experimental test engineer Teresa Borman is supervisor of data acquisition and processing for the Electronics and Parts Test Section.
- At General Electric's Turbine Marketing Division in Schenectady, New York, Nancy Fitzroy, Manager of Energy/Environmental Programs, has been elected the first woman President of the American Society of Mechanical Engineers.
- Contract Administrator Dona Corsini at United Technologies' Hamilton Standard Division supervises preparation of proposals and quotations, negotiations and review of contracts that range in value from $100 to multimillions.
- Senior design engineer Donna Grossman, as designer of the Space Shuttle flash evaporator heaters, received NASA's prestigious "Silver Snoopy" award, given for outstanding contributions to the space program.
- At Hercules Aerospace Company's Products Group Ruth L. Novak is manager of all Navy programs, including development and production of Navy rocket motors.
- At Lockheed-Georgia Company, Gisella W. McClellan is senior structures engineer working almost exclusively on the C-5B transport program.
- At Honeywell, Inc., Dr. Jill Wittels is Manager of Component Engineering Programs in the Electro-Optics Division; Rebecca M. Grant is the Controller of the Aerospace and Defense/Commercial Aviation Division; and Lee Essrig, is senior legal counsel for the Space and Strategic Avionics Division.
- Betty Pears at LTV Aerospace & Defense Company's Vought Aero Products Division, as director of A-7 Corsair technical operations, oversees 250 managers, scientists and engineers in the design and testing of the A-7 basic and growth configurations for both domestic and international markets.
- Dr. Sheila M. Gibbons is Vice President

Yvonne C. Brill of RCA's Astro-Electronics Division, holds a U.S. patent for her design which enables a spacecraft to change its orbit in space.

Second Lt. Kathleen Rambo of the Air Force Reserve walking towards her T-38.
U.S. Air Force Photo

Edna Gardner White at 70 built her own airport, where she lives and teaches flying. Today, at 84, she still instructs daily and still competes in air races. Shown here with some of her more than 100 first place trophies.

Sperry's aerospace software engineer Christa Nolte demonstrates a flight management system simulator to senior project engineer Jeanne Perillo (center) and project software engineer Jeanne Panuska.

Lieutenants junior grade Cathy Beirne and Vicki Karnes, both qualified aircraft commanders, conducted the first search and rescue mission ever flown by Coast Guard women pilots, June 3, 1985.

Captain Nancy Jane Sherlock, an Army Instructor pilot, scheduled to attend the Navy Test Pilot School, is a nominee for NASA Mission Specialist.

The thousands of loyal, enthusiastic viewers of Hill Street Blues, of course, know officer Lucy Bates, but may not know in the real world she is Betty Thomas, a helicopter pilot, and has her own Robinson R-22 helicopter—named "Star Flite."

Lt. Commander Collen Nevius received her Navy wings in 1979. Now qualified in both fixed wing aircraft and helicopters, she is the first woman gradaate of the Navy's Test Pilot School and the first woman member of the Society of Experimental Test Pilots. She and her Navy Lt. Commander husband William F. Readdy are stationed in Norfolk, Virginia.

At the Northrop Corporation's Aircraft Division, Jane Hansen is the Manager of Avionic Test and Evaluation supervising the work of 23 staff members.

and Corporate Secretary of Northrop Corporation and Maria T. Oharenko is Manager of Corporate Press Relations.

- At Northrop's Electro-Mechanical Division, Margo Parker is Vice President of Human Resources.
- At Sperry Corporation's Headquarters Data Center, Sandra Rush is the director of a staff of 160 that supports Sperry's world-wide operators.
- Charlene A. Etheridge, a senior staff engineer at RCA's Communication & Information Systems Division, designed interactive simulation models as part of a study for the NASA Space Shuttle.
- Elaine T. Herfurth is an Engineering Manager-Mechanical Systems at RCA's Missile & Surface Radar Division.
- As Manager of Project Engineering in Vehicle Test Systems, Debbie A. O'Connell of RCA Automated Systems leads a program to design, develop, validate and test a diagnostic system for the improved M109 Howitzer.
- At Rockwell International, Mary Lou Kromer is Director of Market Development with responsibility for public relations, advertising, trade shows, government and community relations; Melissa Van Valkenburgh, Director of Financial Planning & Analysis, establishes Rockwell's annual operating plans and budgets; and Florine Klatt Cain is a project engineer on the Minuteman missile.
- At United Technologies Pratt & Whitney division, Peggy L. Kay is Manager of Community Relations for the division's Connecticut, Maine and Georgia operations; Judith La Drew is executive assistant to Pratt & Whitney's president; and Dorothy Dumezius is Director of Personnel & Industrial Relations for the Government Products Division.
- Vice President of Human Resources for the 14,000 employees of United Technologies' Sikorsky Aircraft Division is Regina H. Hitchery.
- Naomi J. McAffee is Manager of Engi-

CAN

Thanks to CAN – Corporate Angel Network, Inc. – many corporations, not just those in aerospace, have a new image – a caring one.

CAN, a non-profit, volunteer-staffed organization headquartered at New York's Westchester County Airport, provides free flights on corporate aircraft (both fixed and rotary wing) for cancer patients to and from treatment centers across the United States. Co-founded December 21, 1981 by cured cancer patients Priscilla Blum and Jay Weinberg, CAN's 425 kindly corporate members and their fleet of 7,000 aircraft have transported 11,000 patients.

neering Operations at Westinghouse Electric Corporation's Defense & Electronics Center.

- Freeda Suzanne Jenniches, Manager of the Advanced Development Operations at the Westinghouse Center, is responsible for the manufacturing, planning and full scale development hardware for all emerging programs for the Aerospace Command and Control and SYSCOM Divisions.

This sampling of women in industry is evidence that women have taken not one but several giant steps and are recognized professionals in today's specialized high technology careers.

AIRLINES

In 1973, First Officer Emily Howell Warner of Frontier Airlines, Inc. was the first American woman to fly for a major airline and the first woman member of the Air Line Pilots Association. Today, 19,000-hour Captain Warner and more than 500 other women are captains, co-pilots and flight engineers for the major, regional and commuter airlines.

In 1984, People's Express Captains Lynn Ripplemeyer and Beverly Burns set a new record when Captain Ripplemeyer became the first woman to pilot a jumbo jet on a trans-Atlantic flight and Captain Burns the first to pilot a wide-body transport on a trans-continental flight.

Other up-the-ladder achievers are: former American Airlines Flight Attendant Jane Warriner, now Staff Vice President, In-Flight and Reservations for New York Airlines, Inc.; former Republic Airlines Flight Attendant Linda A. Puchala, now President of the Association of Flight Attendants AFL-CIO, representing 23,000 men and women flight attendants on 15 carriers – from regional to national and domestic to international.

COMMUNICATIONS

In aerospace, communications is an expanding field for women – not only in industry but in the media.

For example: Carol A. Shifrin is Dallas Bureau Chief for *Aviation Week & Space Technology* magazine; Joan Lowden is editor of *Aviation Daily;* Kim Smith is editor of the *Helicopter Annual;* Kelly Quinn is managing editor of *Professional Pilot* magazine; and Kathryn K. Gibson is managing editor of *Air Transport World.* Elaine Asch is President and Editor of *Revista Aerea* magazine and is also Vice President Regions of the Aviation/Space Writers Association.

More and more women are holding key positions in aerospace related organizations.

At the Helicopter Association International, with more than 1,000 members in more than 40 countries, Wanda Rogers is chairman of the board, the second woman to hold this top position. Mrs. Rogers and her husband, with a fleet of 16 helicopters, operate Rogers Helicopters, Inc. in Clovis, California.

Aerospace Industries Association's Vice President of Civil Aviation is Celia Sherbeck; the Director of the Research Center is Virginia Lopez, Susan Walsh is Assistant Legislative Counsel and manager of information in the Office of Public Affairs is Ellen Kelly.

Manager of Education Programs at the National Business Aircraft Association is Ann W. Devers.

Director of Communications at the Aircraft Owners & Pilots Association is Patricia E. Well.

At Air Transport Association, Pamela Clark is Vice President, Administration and Treasurer.

MILITARY

The WASPS (Women Airforce Service Pilots) pioneered as civilian pilots in World War II for the then Army Air Forces.

In 1973, the Navy was the first service to open aviation training to women. The Army followed in a few months. Next came the 2nd generation of women U.S. Air Force pilots in 1976. There are no women pilots in the U.S. Marine Corps.

Today, there are 126 women naval aviators flying all types of aircraft – from jet fighters to cargo transports to the largest helicopter in the inventory. The 255 women Army aviators (officers and warrant officers) are qualified to fly all Army helicopters. In addition, there are 14 female fixed wing aviators in the Army National Guard. The Air Force has 290 women fighter and transport pilots and 125 women navigators. In the peacetime U.S. Coast Guard, there are nine active women pilots and five in flight training.

In commercial aerospace, women are engaged in a wide range of pursuits, for example, aerial advertising, crop dusting, designing flight suits, fighting forest fires, hunting hurricanes, making trans-Atlantic delivery flights, piloting corporate aircraft, directing aviation education programs, operating airports/heliports and flight schools, reporting traffic and weather, flying rescue and emergency medical missions.

In the past, secretarial jobs have been the traditional route for women who want a career. But in today's aerospace job market, non-traditional careers have opened for women. Women who major in mathematics, science, engineering and medicine have permeated all branches of industry and phases of the space program. Today, flight instructor has become the first step or take-off toward becoming an airline pilot. Many of today's male airline pilots were trained by women instructors and women FAA flight examiners gave them their check ride.

Aerospace career opportunities for women are limitless. The weather forecast acronym CAVU (Ceiling And Visibility Unlimited) might be applied to describe the future for women in aerospace: Careers And Vocations Unlimited.

From flight attendant to captain, Lynn Rippelmeyer is a captain with People Express Airlines, was the first to captain a Boeing 747 jumbo jet across the Atlantic and one of two women in the world to fly this jet transport.

The only woman scheduled airline owner/operator is Virginia "Gini" Richardson, owner/manager/chief pilot (with more than 25,000 flight hours) of Richardson Aviation in Yakima, Washington. Gini operates a fleet of twin-engine Cessna 402s in scheduled courier-freight hauling in the Pacific Northwest.

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